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Pacific Herring Biomass in the Northern Montague Island and Knowles Head Areas of Prince William Sound, Alaska, in the Spring of 1998

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ABSTRACT

An acoustic and net sampling survey was conducted in the vicinities of northern Montague Island and Knowles Head in Prince William Sound between 23 and 27 March 1998 to estimate the acoustic biomass of pre-spawning Pacific herring. Initial reconnaissance to locate schools, acoustic surveys, and net catches were conducted using two purse seine vessels equipped with both scientific echosounders and small mesh purse seines. Acoustic surveys consisted of replicated transits along evenly spaced parallel transects to obtain average density of acoustic targets. Transects were generally orthogonal to the shoreline and covered spatial strata on the scale of major bays. All surveys were conducted at night. Purse seine and cast net catches were used to identify acoustic targets, verify assumptions about target strength, and estimate age composition for calculating the biomass of herring in the acoustic biomass that would likely have participated in spawning. The total acoustic biomass covered by surveys was estimated at 19,803 tonnes, 17,294 tonnes in the Montague Island area and 2,509 tonnes in eastern Prince William Sound. The estimated spawning acoustic biomass for PWS (15,837 tonnes) was approximately 4,000 tonnes less than the acoustic biomass, primarily due to the high abundance of pre-recruit ages 2, 3, and 4.

INTRODUCTION

Acoustic stock assessment techniques (MacLennan and Simmonds 1992) were used to estimate the acoustic biomass of major concentrations of pre-spawning Pacific herring *Clupea pallasii* during the spring of 1998 in Prince William Sound (PWS), Alaska. Spring acoustic surveys have been conducted annually in PWS since 1995 (Willette et al.1998, Kirsch and Thomas 1997, Willette et al. 1997, Thomas et al.1996, Thorne et al. 1996) to track changes in spawning herring abundance over time.

Spring acoustic surveys evolved from fall surveys, which have been attempted in PWS sporadically since the late 1970s (Gaudet 1982, DeCino et al. 1994, Thomas et al. 1995). Fall surveys typically targeted herring aggregations during October or November in areas where herring were historically observed to overwinter, and were developed from techniques applied in Southeastern Alaska (Thorne and Moberly 1974). Because mortality between the time of fall overwinter migration and spring spawning migration can sometimes be substantial (Funk 1995, or Willette et al. 1998), spring surveys were initiated to estimate the biomass immediately prior to the large sac roe harvest and after most winter is assumed to have occurred. Acoustic surveys were also implemented as a less expensive alternative means of estimating spawning population abundance. Stock assessments from spawn deposition surveys, which are more expensive than than acoustic surveys, were historically used to estimate spawning abundance (Willette et al. 1998) and are generally believed to be more comprehensive. Spawn deposition surveys are no longer conducted due to their expense and the logistical difficulties for this technique.

The areas chosen for surveys were based on local fishermen's knowledge and past experience of herring distribution. The surveys were not designed to locate and quantify all pre-spawning herring aggregations in PWS, but were intended to cost-effectively locate and survey as many herring schools as possible in commonly occurring areas, within the temporal and monetary constraints of the project.

Previous spring acoustic surveys were conducted directly from funding for *Exxon Valdez* oil spill Trustee Council project Herring Natal Habitats to investigate alternative methods of estimating spring spawning herring biomass (Willette et al.1998). More recently, the project has been funded primarily from State general funds and test fishing, but has also relied on contributions from cooperating agencies. The 1998 survey employed a state vessel funded under State general funds, a second vessel and a professional services contract funded under the PWS Herring Test Fishing project, and acoustic equipment on permanent loan from Cordova District Fishermen United. This report documents the detailed methods and results of surveys conducted by ADF&G personnel, and summarizes results from the professional services contractor aboard the second vessel. Details of survey methods and results from the professional services contractor are included in their final report to ADF&G (Appendix A).

METHODS

Field Data Collection

All surveys were conducted between 23 March and 27 March 1998. The areas covered included the northern end of Montague Island, shorelines and bays in the Knowles Head area, and the northern side of Sheep Bay (Figure 1; Appendix A, Figure 1). A brief reconnaissance of bays in Port Gravina did not identify sufficient concentrations of pre-spawning herring for acoustic surveys.

Two vessels, a state-owned research vessel (*R/V Montague*) and a private commercial purse seine vessel under short-term vessel charter (*F/V Miss Kayley*) worked in concert to conduct concurrent searches, surveys, and fish sample collections in adjacent areas. Both vessels were equipped with scientific echosounders for collecting acoustic data and a small mesh purse seine for collecting biological samples. Personnel aboard the *F/V Miss Kayley* included one person in the employ of the professional services contractor, the Prince William Sound Science Center (PWSSC), operating acoustic equipment as described in Appendix A. This report details primarily the collection of acoustic data by ADF&G personnel stationed aboard the *R/V Montague.*

All surveys were conducted between dusk and dawn. Typically, the two vessels performed a similar routine each evening consisting of a general reconnaissance within a bay to locate herring concentrations, followed by one or more purse seine sets to collect fish samples until full darkness. After dark, a sampling pattern was agreed upon between the project leaders and vessel skippers taking into account weather, time, bathymetry, and herring school distribution. The preferred sampling grid consisted of parallel transects spaced approximately 0.2nm apart and orthogonal to the main shoreline. Transect spacing was frequently modified to conform to shoreline or bottom features and to cover sufficient sampling area within the available time of darkness. Where convenient, Loran lines were used to orient parallel transects. Zigzag transects were sometimes used to cover a greater area if available time was constrained and herring school density was low. In general, both vessels conducted acoustic surveys along the agreed sampling pattern until dawn, repeating the survey grid as many times as darkness allowed. Surveys were occasionally interrupted to conduct fishing if earlier sampling had been unsuccessful. During most nights, the two vessels surveyed adjacent areas to maximize the sampling area covered in a single night. On one occasion, 24 March, the two vessels each completed two replicate surveys over the same area within Stockdale Harbor to compare survey variability.

Several large geographic strata were established based on herring densities observed in previous years and spring aerial surveys. Whenever time allowed, replicate surveys were conducted for each stratum. The location and length of each transect were determined using coordinates recorded from a GPS. Each survey replicate within a stratum was assigned a survey code consisting of a two character location code, six digit date (including two digit year), and a one character code for replicate (A, B, or C). Location codes for strata were SH for Stockdale Harbor, RB for Rocky Bay, ZB for Zaikof Bay, and KH for Knowles Head.

The scientific acoustic equipment aboard the *R/V Montague* consisted of a BioSonics DT4000 70kHz digital echosounder with a single beam transducer mounted in a downward looking configuration on a 1.2m BioFin. The BioFin was towed alongside the vessel from a stabilizer pole about 3m off to one side and 2m below the surface. Positional data were recorded using an internal Global Positioning System (GPS) system installed in the echosounder by the manufacturer.

Acoustic data were collected using BioSonics Visual Acquisition software version 2.1.2 running on a pentium 90mHz laptop computer. Data were initially stored on the hard disk drive of the laptop and copied to an Iomega Ditto tape drive at the end of each nightly session. Each data file was automatically assigned an eight-digit file name consisting of the time that data recording began to the nearest hundredth of a second, and a file extension of "dt4". Raw data files for a single stratum replicate were reorganized from the default subdirectory structure, based on date by the acquisition software, into subdirectories bearing the name of the corresponding survey code.

Initial parameters for the echosounder and data acquisition software were set for a linear data threshold of -90dB, a pulse duration of 0.5ms, and a trigger interval of 0.5s (2 pings/s). The minimum and maximum range settings of the sonar were set according to surface noise conditions and an *a priori* guess of the bottom depth for each transect. Maximum depth range settings did not exceed 60m.

The purse seine aboard the *R/V Montague* was a 35m deep anchovy seine with a stretch mesh size of 15mm. Samples from net catches aboard both vessels taken in nearby areas were pooled to describe size and age composition of acoustic targets. For the Stockdale Harbor stratum, samples from test fishing for commercial sac roe fisheries and samples from cast net catches in active spawn were also pooled with samples from purse seine catches. This was done, because net catches collected during the acoustic survey were not felt to adequately represent the large number of highly mobile schools observed in the area during surveys.

Descriptions of the acoustic equipment operated under contract by the Prince William Sound Science Center and the fishing gear aboard the second vessel are detailed in Appendix A.

Data Analysis

Raw acoustic data were processed after field surveys were concluded using BioSonics Visual Analyzer software version 3.0.0. Echo integration results from the Visual Analyzer software were imported into Excel97 for summarization and variance was calculated using programs written for SAS version x.x.

Water temperature and salinity values were set in the analysis software at 5.61°C and 31.45ppt, based on the observations of SEA oceanographic researchers in mid-March (Sheri Vaughn, Prince William Sound Science Center, personal communications). These temperature and salinity values yielded an absorption coefficient of 5.5×10^{-3}dB/m and an estimated speed of sound in seawater of 1.473 km/s for 70kHz sound waves. These values were calculated automatically in the analysis software.

All automated bottom tracking results were verified by visual examination of echograms and were manually edited to prevent inclusion of bottom and exclusion of obvious fish schools in the integration analysis. Automated bottom tracking routines included in the analysis software are intended to prevent inclusion of bottom echoes in integration results. However, dense schools could not always be distinguished from bottom echoes and echoes where schools existed very near the bottom were often misidentified, even after extensive adjustment of bottom tracking parameters. Although manual editing of echograms was subjective and accuracy depended on the observer's interpretations of visual displays, editing criteria were applied conservatively to minimize the possibility of integrating bottom echoes.

Echo integration was used to determine the density of acoustic targets within each depth interval using methods similar to Willette et al. (1998). The echo integral (E_k) for depth interval k is given by

$$E_k = \int_{t_1}^{t_2} |v(t)|^2 \, dt$$

where v(t) is the voltage produced by the echosounder at time t. The time gate t_1 to t_2 was chosen to correspond to a specific depth interval to be sampled (Ehrenberg and Lytle 1972).

Each sample transect was divided into j elementary distance sampling units (EDSU). The length of the EDSU's was chosen to minimize serial correlation without unnecessarily eliminating information on fish distribution. A minimum number of EDSU's was arbitrarily set at 30 per transect to meet or exceed these criteria in all instances. The mean echo integral (E_{jk}) was calculated for each depth interval-EDSU cell (MacLennan and Simmonds 1992). The biomass of fish per unit area in each cell (β_{jk}) is given by

$$\beta_{jk} = [(C \bar{g} / \Psi < \sigma >)] \; E_{jk}$$

where C is a calibration factor, g is the mean TVG correction factor, Ψ is the equivalent beam angle (a measure of beam width), $\langle \sigma \rangle$ is the mean acoustic cross section per unit weight of the target, and E_{jk} is the mean echo integral (MacLennan and Simmonds 1992).

Herring target strength was estimated from a relationship between mean length and target strength (in decibels) per kg of fish (Thorne 1983a) using mean lengths of herring in each stratum estimated from net samples. Thorne's (1983a) empirical relationship assumes the following logistical equation:

$$\gamma = \frac{\bar{\sigma}}{\bar{W}} = a\,\bar{l}^{-b}$$

where σ is the mean acoustic backscattering coefficient, W is the mean weight (kg), l is the mean tip-of-snout to fork-of-tail length (cm), and a and b are constants. Values for the constants (a and b) were obtained from data for a variety of fisheries presented by Thorne using a linear regression of $\log_{10} l$ versus 10 log (σ/w), where 10 log (σ/w) was referred to in Thorne (1983a) as "target strength per kg." Average herring length and weight data were compiled from samples obtained either from purse seine catches during the acoustic survey, samples captured by commercial sac roe seine vessels shortly after the survey, or from cast net samples collected from actively spawning fish in nearby areas. These measured data were applied to Thorne's (1983a) empirical relationship to obtain the ratio γ = σ/w and the mean backscatter coefficient (σ).

For each stratum, the mean biomass per meter squared of herring along the *i*th transect in the *h*th replicate (β_{ih}, kg m^{-2}) is given by

$$\bar{\beta}_{ih} = \frac{\sum_j \sum_k \beta_{jk}}{n_{jk}}$$

where n_{jk} is the number of depth interval-EDSU cells in the *i*th transect (MacLennan and Simmonds 1992). The biomass sampled in the *h*th replicate for each stratum (β_h, kg m^{-2}) is estimated from

$$\bar{\beta}_h = \sum_i \left(\bar{\beta}_{ih}\, w_{ih}\right)$$

where w_{ih} is the area (m^2) of a polygon around the *i*th transect defined as being bounded by lines connecting the ends of adjacent transects and lines midway between adjacent transects on each side of the *i*th transect in the *h*th replicate (Figure 2; and Appendix A). The variance of β_h is given by

$$Var(\bar{\beta}_h) = \sum_i W^2_{ih} \frac{S_h^2}{n_h} + 2 \sum_{i <} \sum_j W_{ih} W_{jh} Cov(B_{hi}, B_{hj})$$

where

$$S_h^{\,2} = \sum \frac{(\beta_{ih} - \bar{\beta}_h)^2}{(n_h - 1)}$$

where n_h is the number of transects in replicate *h* of the stratum (Thompson and Seber 1996). A covariance term was included in the biomass variance estimate to account for autocorrelation among transects.

The total biomass of herring in each survey area stratum (β, kg) is then given by

$$\beta = \frac{\sum_h \overline{\beta_h}}{h}$$

The variance of β is given by

$$Var(\beta) = \sum_h Var(\overline{\beta_h})$$

The contribution of each age class by weight to the total acoustic biomass for each survey area stratum was estimated by

$$\beta_{ah} = P_{ah}\beta_h$$

where β_{ah} is the biomass of herring that was age *a* in the acoustic biomass and P_{ah} is the proportion by weight of herring that were age *a* in purse seine or cast net samples from the *h*th stratum. Contribution of each age class by weight to the spawning biomass for each survey area stratum was estimated by

$$S_{ah} = R_a\beta_{ah}$$

where S_{ah} is the biomass of herring that were age *a* in the acoustic biomass that recruited into the adult spawning population of stratum *h* and R_a is the estimated proportion of herring of age *a* recruiting into the spawning population, obtained from Age Structured Assessment (ASA) modeling (Wilcock, in prep).

Total acoustic biomass and spawning acoustic biomass estimates for replicate surveys from a survey area stratum were averaged where replicates were subjectively judged from field notes and integration results to adequately represent herring schools in the area (Zaikof Bay, Rocky Bay, and Stockdale Harbor). Replicate surveys that did not appear to represent observed fish distribution (e.g. schools were observed on ships sonar outside the surveyed area), were excluded. Average total acoustic biomass from adjacent areas surveyed in one night by the different vessels (Zaikof Bay and Rocky Bay; Knowles Head, St. Matthews Bay, and SheepBay), and average acoustic biomass estimates from an adjacent area surveyed on the next night (Stockdale Harbor), were summed to estimate total acoustic biomass for major geographic areas (Montague Island or Eastern Prince William Sound). Spawning acoustic biomass estimates from adjacent areas were summed in the same manner.

RESULTS

Two or more replicate surveys were completed aboard the *R/V Montague* for strata in Zaikof Bay, Rocky Bay, and Stockdale Harbor (Table 1, Figure 2). Only a single replicate of the Knowles Head area was completed due to weather and limited available time of darkness.

Data from 11 sample collections from net catches were deemed suitable for estimating age composition and average size, identifying species, and estimating target strength parameters of acoustic targets (Table 2). Because all catches consisted of nearly 100% herring, acoustic targets were assumed to be all herring. Samples collected from individual purse seine sets or from cast net sampling in a specific location were pooled to represent herring for each of four spatial strata covered by the surveys. Average length and mean acoustic backscattering coefficients were similar for herring samples from all four geographic strata (Table 3). Age-4 herring from the 1994 year class were the most abundant in all strata, ranging from 30.0% by weight in samples from the vicinity of Stockdale Harbor to 39.8% in samples from Knowles Head. Age-3 herring exceeded 21% in all Montague Island strata.

Acoustic biomass estimates for individual transects ranged from near zero to slightly less than 4,700 tonnes (Table 4). The largest concentration of herring (8,600 tonnes) was observed in acoustic biomass estimates from two transects in Zaikof Bay on the morning of 24 March (transect numbers 8 and 9). GPS positional data for one replicate survey in Rocky Bay on the night of 25 March were not recorded, and acoustic biomass was not estimated for that replicate.

The largest acoustic biomass estimate from a single ADF&G survey replicate (11,699 tonnes) occurred on the night of 23 March in Zaikof Bay (Table 5). However, acoustic biomass for an earlier replicate in the same location, was approximately half that estimate (6,144 tonnes). Because area swept estimates for each transect were somewhat larger during the second replicate and because most schools were concentrated along one end of only two transects, biomass estimates from the two replicates were averaged to minimize the possibility of overestimating abundance due to chance school distribution. Acoustic biomass estimates from two ADF&G replicates in Stockdale Harbor were similar, as were the two valid replicates in Rocky Bay (Table 5). Estimated acoustic biomass for each area stratum was the average of the two replicates in each area. The smallest ADF&G acoustic biomass estimate (1,192 tonnes) occurred near Knowles Head for a single replicate that covered a large ($2.5\text{x}10^7\text{m}^2$) geographic area (Table 1).

Replicate surveys conducted by PWS Science Center (Appendix A) also indicated that the largest concentration of herring schools (7,454 and 9,567 tonnes) occurred in Zaikof Bay (Table 6). The average acoustic biomass (8,511 tonnes) was similar to the average acoustic biomass (8,921 tonnes) observed two nights earlier during ADF&G surveys in this area. Because of school distribution observed by ships sonar in Rocky Bay on the night of 23 March, the peak acoustic biomass observed during PWSSC surveys was chosen to represent acoustic biomass for this area stratum. The sum of average acoustic biomass estimates from Zaikof and Rocky Bays, surveyed by the different vessels on the night of 23 March (14,845 tonnes), was greater than estimates (11,703 tonnes) two nights later (Table 7).

Acoustic biomass estimates for PWSSC transects in Stockdale Harbor on the night of 24 March (847 and 550 tonnes) were very low relative to ADF&G estimates over a similar area (2,782 and 2,115 tonnes). Although both vessels surveyed similar areas (Figure x; Appendix A, Figures 6 and 7), the two vessels covered slightly different cruise tracks. It was felt that PWSSC transects missed a substantial portion of the herring schools present at that time, primarily due to a large dense school beyond a shallow ridge over which the vessel captain did not wish to travel for safety concerns. PWSSC replicate surveys for that night were not used to estimate acoustic biomass and results only from *R/V Montague* replicate surveys were used to estimate average acoustic biomass. Average acoustic biomass estimates from surveys for both vessels on the night of 23 March and from the *R/V Montague* survey on the night of 24 March were summed to estimate total acoustic biomass (17,294 tonnes) and spawning acoustic biomass (13,683 tonnes) for the Montague Island area (Table 7).

Small acoustic biomass estimates were also obtained for St. Matthews (1,041 tonnes) and Sheep (276 tonnes) Bays. Single replicates of surveys in adjacent areas by the two vessels were summed to estimate the total acoustic biomass (2,509 tonnes) and spawning acoustic biomass (2,154 tonnes) for eastern Prince William Sound.

DISCUSSION

The estimated spawning acoustic biomass for Prince William Sound in 1998 (15,837 tonnes) was less than 4,000 tonnes lower than estimates of total acoustic biomass, primarily due to the large number of pre-recruit age-2, -3, and -4 herring in samples from net catches.

Surveys in 1998 differed somewhat from 1997 surveys in two important respects. In 1998 effective transect surface area was used to weight individual transect densities to estimate acoustic biomass for a survey. Previous analyses used transect length to weight individual transect densities. Appendix A includes a discussion of potential sources of error using these methods. Weighting by effective surface area can result in an overestimate of biomass if transect spacing is closer in areas of high target density than in areas of low density. This was not felt to be a problem during the 1998 ADF&G surveys, because transect spacing was relatively consistent and because results from replicate surveys were averaged.

Secondly, the duration of the cruise was much shorter in 1998 than in 1997. Because of this, the area covered was smaller and less time was available for searching for major school concentrations. This incomplete coverage of the entire spawning population precludes the use of acoustic surveys to estimate total spawning biomass in PWS. Therefore, acoustic biomass information from spring surveys was incorporated into Age Structured Assessment (ASA) models (Wilcock, in prep.) not as an indicator of total spawning biomass, but rather as a lower constraint to spawning biomass estimated by the model. In effect, the assumption is made that spawning biomass could have been no less than that observed in acoustic surveys. In general, ASA estimates of spawning biomass were well above the lower constraints based on acoustic biomass, and inclusion of the information did not alter results of the model. Although results were not altered, acoustic biomass estimates may become more important in the future as other methods of assessing spawning biomass (e.g. egg surveys) provide progressively less current information about abundance.

Kirsch and Thomas (Appendix A) also include discussion of other sources of error that may apply to acoustic surveys. The problems of selecting appropriate target strength values and extinction of sound apply to ADF&G surveys. Because more studies are needed to clarify these issues, the same assumptions about target strength and sound extinction were applied ADF&G surveys as for PWSSC surveys. Additional information on target strength will become available with completion of an investigation currently underway by PWSSC. All recorded echograms of ADF&G surveys were visually examined and edited to verify echo identification and minimize misidentification of bottom and school echoes.

LITERATURE CITED

DeCino, Robert, J. Wilcock, E. V. Patrick, R. E. Thorne, and G. L. Thomas. 1995. Acoustic estimate of herring biomass in the Green Island area of Prince William Sound, Alaska, 1993. Regional Information Report No. 2A95-27, Division of Commercial Fisheries, Alaska Dept. Fish and Game, Anchorage, AK

Ehrenberg, J.E. and D.W. Lytle. 1972. Acoustic techniques for estimating fish abundance Trans. Geos. Elec. 10: 138-145.

Gaudet, D.M. 1984. Prince William Sound herring survey, 1982. Alaska Dept. of Fish and Game, Division of Commercial Fisheries, Juneau, Alaska. 57 p.

Kirsch, J. and G.L. Thomas. 1997. Acoustic biomass estimate of adult herring in Prince William Sound, Alaska, in spring 1997. Final report to the Alaska Dept. of Fish and Game, Prince William Sound Science Center, P.O. Box 705, Cordova, Alaska 99574.

Love, R.H. 1977. Target strength of an individual fish at any aspect. Journal of Acoustic Society of America. 62:1397-1403.

MacLennan, D.N. and E.J. Simmonds. 1992. Fisheries Acoustics. Chapman & Hall. London. 325 p.

Thomas, G.L., J. Kirsch, P. Salamone, and J. Wilcock. 1995. Pacific herring biomass in the Knowles Head and Green Island area of Prince William Sound, Alaska, in the fall of 1994. Regional Information Report No. 2A95-43. Division of Commercial Fisheries, Alaska Dept. of Fish and Game, Anchorage, Alaska.

Thomas, G.L., J. Kirsch, D. Thorne, J. Wilcock. 1996. Acoustic estimate of herring biomass in Rocky Bay and Stockdale Harbor, Prince William Sound, in the spring of 1996. Final report to the Alaska Dept. of Fish and Game, Prince William Sound Science Center, P.O. Box 705, Cordova, Alaska 99574.

Thorne, R.E. 1983a. Assessment of population abundance by echo integration. Biol. Ocean. Journal 2:253-262.

Thorne, R.E. 1983b. Hydroacoustics. Chap. 12 in L. Nielson and D. Johnson (eds). Fisheries Techniques. American Fisheries Society. Bethesda, MD.

Thorne, R.E. and S. Moberly. 1974. Assessment of southeastern Alaska herring stocks using hydroacoustic techniques. 1970-72. Alaska Department of Fish and Game Informational Leaflet 1965. 22 p.

Thorne, D., G.L. Thomas, and J. Wilcock. 1996. Acoustic estimate of herring biomass in Rocky and Zaikof Bays, Prince William Sound, in the spring of 1995. Final report to the Alaska Dept. of Fish and Game, Prince William Sound Science Center, P.O. Box 705, Cordova, Alaska 99574.

Thompson, S.K. and G.A. Seber. 1996. Adaptive Sampling. John Wiley & Sons, Inc, New York.

Wilcock, J. A. In prep. Age structured analysis of Pacific herring from Prince William Sound, Alaska, 1998. Regional Information Report No. 99-2Axx, Division of Commercial Fisheries, Alaska Dept. of Fish and Game, Anchorage, Alaska.

Willette, T. M., G.S. Carpenter, and K. Hyer. 1997. Herring spawn deposition and reproductive impairment, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 96166), Alaska Department of Fish and Game, Cordova, Alaska.

Willette, T. M., G.S. Carpenter, K. Hyer and J. Wilcock. 1998. Herring Natal Habitats, *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 166), Alaska Department of Fish and Game, Cordova, Alaska.

Table 1. Acoustic survey area location, time, and description for pre-spawning herring acoustic surveys in Prince William Sound, Alaska, 1998.

Survey Code	Survey Location	Begin Date	Time		Transects			Area (m^2)
			Begin	End	Orientation	Interval	Number	
ZB032398A	Zaikof Bay	3/23/98	23:30	3:06	Loran Lines	2.5 ms	16	6.26E+06
ZB032398B	Zaikof Bay	3/23/98	3:38	5:17	Loran Lines	2.5 ms	11	4.91E+06
SH032498A	Stockdale Hbr	3/24/98	20:32	22:07	Parallel	0.1 nm	11	1.82E+06
SH032498B	Stockdale Hbr	3/24/98	23:10	0:31	Parallel	0.1 nm	14	1.03E+06
RB032598A	Rocky Bay	3/25/98	22:08	23:59	Loran Lines	2.5 ms	13	1.70E+06
RB032598B	Rocky Bay	3/25/98	0:31	1:53	Loran Lines	2.5 ms	19	1.71E+06
RB032598C	Rocky Bay	3/25/98	2:02	2:53	Loran Lines	2.5 ms	8	7.76E+05
KH032798A	Knowles Head	3/27/98	19:55	0:30	Parallel/ZigZag	arbitrary	22	2.51E+07

Table 2. Sample collections of pre-spawning herring from purse seine and cast net catches used to identify species, estimate age composition, and acoustic target strength parameters for acoustic surveys conducted by ADF&G personnel, Prince William Sound, Alaska, 1998.

Survey Stratum	Fishing Locations	Date	AWL Samples	No. of Sets	Gear Type	Vessel
Zaikof Bay	Zaikof Bay	3/23/98	9812tpzb	1	Anchovy Seine	R/V Montague
	Zaikof Bay	3/24/98	9802tpzb	1	Anchovy Seine	F/V Miss Kayley
Stockdale Hbr	Stockdale Hbr	3/24/98	9803tpsh	1	Anchovy Seine	F/V Miss Kayley
	Stockdale Hbr	4/2/98	9805tpsh	1	Sac Roe Seine	F/V Miss Vicky
	Gilmour Pt	4/4/98	9807tppc	1	Sac Roe Seine	F/V Miss Vicky
	Stockdale Hbr	4/6/98	9810tpsh	1	Sac Roe Seine	F/V Thalassa
	Graveyard Pt	4/12/98	9811tcgp		Cast Net	R/V Montague
	Port Chalmers	4/12/98	9814tcpc		Cast Net	R/V Montague
Rocky Bay	Rocky Bay	3/24/98	9804tprb	1	Anchovy Seine	F/V Miss Kayley
	Rocky Bay	3/25/98	9806tprb	1	Anchovy Seine	R/V Montague
Knowles Head	Knowles Head	3/27/98	9801tpsm	1	Anchovy Seine	R/V Montague

Table 3. Age composition by wieght of herring sampled from purse seine and cast net catches for acoustic target identification for acoustic surveys of pre-spawning herring in Prince William Sound, Alaska, spring 1998.

Survey	Surveys	Age												Average Length		TS_w (Thorne)		TS (Love)	
Stratum	Represented	2	3	4	5	6	7	8	9	10	11	12	13	(mm)	n	dB/kg	s	dB	m^2
Zaikof Bay	ZB032398A, B	0.1%	21.6%	33.9%	11.6%	14.0%	1.2%	4.3%	1.9%	10.0%	0.6%	0.0%	0.8%	216.65	893	-32.22	6.00E-04	-36.82	2.1E-04
Stockdale Hbr	SH032498A, B	0.1%	22.1%	30.0%	8.8%	12.6%	1.3%	4.5%	2.1%	16.5%	0.3%	0.6%	1.1%	221.57	2482	-32.28	5.92E-04	-36.62	2.2E-04
Rocky Bay	RB032598A, B, C	0.2%	21.2%	34.6%	9.9%	12.1%	1.9%	3.4%	1.6%	13.9%	0.4%	0.0%	0.8%	217.00	895	-32.23	5.99E-04	-36.80	2.1E-04
Knowles Head	KH032798A	0.0%	11.3%	39.8%	11.1%	13.1%	2.1%	6.5%	1.4%	12.7%	0.4%	1.2%	0.4%	222.91	445	-32.30	5.89E-04	-36.57	2.2E-04

Table 4. Echo integration results for each transect from pre-spawning herring acoustic surveys conducted aboard the *R/V Montague*, PrinceWilliam Sound, Alaska, 1998.

Survey	Transect				Mean Fish	Acoustic Biomass	
Code	Filename	No.	Length (km)	Area (m^2)	Denstiy (kg/m^2)	kg	tonnes
KH032798A	19553230	1	3.18239	2,638,732	0.01208	31,883	31.9
KH032798A	20212479	2	4.30957	3,700,114	0.03115	115,245	115.2
KH032798A	20555241	3	3.93567	3,486,834	0.05753	200,601	200.6
KH032798A	21291046	4	1.01331	1,431,418	0.02673	38,262	38.3
KH032798A	21460290	5	2.05594	1,091,731	0.06695	73,093	73.1
KH032798A	21593545	6	0.40654	342,353	0.17325	59,312	59.3
KH032798A	22104603	7	0.54218	768,921	0.07823	60,155	60.2
KH032798A	22245215	8	1.23527	1,419,347	0.00878	12,467	12.5
KH032798A	22425417	9	0.68343	1,133,094	0.00717	8,122	8.1
KH032798A	23024981	10	1.22006	2,626,197	0.00728	19,121	19.1
KH032798A	23391260	11	0.65595	1,913,266	0.08205	156,989	157.0
KH032798A	23460905	12	3.60787	2,127,114	0.08155	173,460	173.5
KH032798A	00085063	13	1.01505	1,173,921	0.06575	77,182	77.2
KH032798A	00170380	14	1.3199	506,745	0.06714	34,022	34.0
KH032798A	00261358	15	0.4383	270,255	0.18097	48,908	48.9
KH032798A	00301176	16	1.6556	478,797	0.17460	83,599	83.6
RB032598A	22082554	1	0.26502		0.60043		
RB032598A	22142614	2	0.17712		0.76941		
RB032598A	22231458	3	0.45945		2.24745		
RB032598A	22325234	4	0.84843		3.21904		
RB032598A	22461924	5	1.39458		1.07276		
RB032598A	23010229	6	1.51132		0.57214		
RB032598A	23203821	7	1.84911		0.94700		
RB032598A	23500225	8	0.14457		0.06608		
RB032598A	23552917	9	0.25044		0.00350		
RB032598A	23591840	10	0.02031		0.17204		
RB032598A	23595521	11	0.22630		0.06106		
RB032598B	00310244	1	0.18106	11,185	0.02139	239	0.2
RB032598B	00374181	2	0.26344	85,882	0.01992	1,711	1.7
RB032598B	00452063	3	0.30843		0.03900		
RB032598B	00541120	4	0.51647	185,905	0.05666	10,534	10.5
RB032598B	01040984	5	1.43464	440,092	0.03756	16,531	16.5
RB032598B	01172089	6	1.29259	405,389	0.64051	259,657	259.7
RB032598B	01304253	7	1.00668	252,540	7.27235	1,836,560	1,836.6
RB032598B	01415535	8	0.59694	200,548	3.62529	727,045	727.0
RB032598B	01530125	9	0.34853	123,794	0.00016	19	0.0
RB032598C	02020798	1	0.42088	62,117	0.00056	35	0.0
RB032598C	02072482	2	0.45852	91,127	0.55813	50,860	50.9
RB032598C	02132217	3	0.62511	74,039	1.72913	128,023	128.0
RB032598C	02205278	4	0.83916	148,443	1.23542	183,390	183.4
RB032598C	02285425	5	1.08677	196,589	2.40659	473,110	473.1
RB032598C	02394318	6	0.40222	84,984	5.29033	449,594	449.6
RB032598C	02454647	7	0.46425	51,312	0.91972	47,193	47.2
RB032598C	02534431	8	0.41858	64,526	1.37100	88,465	88.5

Table 4. Continued (pg 2 of 2).

Survey	Transect				Mean Fish	Acoustic Biomass	
Code	Filename	No.	Length (km)	Area (m^2)	Denstiy (kg/m^2)	kg	tonnes
SH032498A	20325013	1	0.35629	34,825	0.01479	515	0.5
SH032498A	20372406	2	0.39006	30,700	0.00257	79	0.1
SH032498A	20432355	3	0.33061	40,630	0.00417	169	0.2
SH032498A	20475327	4	0.38024	35,368	0.09226	3,263	3.3
SH032498A	20565294	5	0.32458	43,293	0.10486	4,540	4.5
SH032498A	21055599	6	0.82284	142,156	3.17673	451,592	451.6
SH032498A	21120967	7	0.62575	230,772	0.31347	72,339	72.3
SH032498A	21224817	8	1.09155	379,857	1.93146	733,679	733.7
SH032498A	21381481	9	0.30252	377,678	2.68748	1,015,002	1,015.0
SH032498A	21494752	10	0.90136	396,519	0.94678	375,414	375.4
SH032498A	22074236	11	0.25321	106,039	1.18396	125,546	125.5
SH032498B	23101686	1	0.18285	19,242	0.95275	18,333	18.3
SH032498B	23170349	2	0.27427	60,259	2.73618	164,879	164.9
SH032498B	23221412	3	0.42223	127,330	1.92545	245,168	245.2
SH032498B	23310431	4	0.32542	89,436	1.90950	170,778	170.8
SH032498B	23365389	5	0.27343	59,893	8.81284	527,827	527.8
SH032498B	23425136	6	0.29041	71,597	3.33305	238,637	238.6
SH032498B	23490819	7	0.27636	104,450	3.65118	381,366	381.4
SH032498B	23552743	8	0.48211	160,707	0.74048	119,000	119.0
SH032498B	00030697	9	0.48916	136,961	1.18740	162,627	162.6
SH032498B	00094380	10	0.23819	46,223	0.40736	18,829	18.8
SH032498B	00151340	11	0.32830	28,242	0.48492	13,695	13.7
SH032498B	00212484	12	0.25229	22,689	0.13738	3,117	3.1
SH032498B	00262362	13	0.35528	28,467	0.28470	8,105	8.1
SH032498B	00314104	14	0.44541	72,515	0.59529	43,168	43.2
ZB032398A	23301986	1	0.35678	88,760	0.02685	2,383	2.4
ZB032398A	23595247	2	0.78512	258,011	0.02341	6,041	6.0
ZB032398A	00120835	3	1.19644	394,155	0.03166	12,480	12.5
ZB032398A	00251542	4	1.50891	545,870	2.63420	1,437,930	1,437.9
ZB032398A	00394277	5	1.83598	673,794	1.06737	719,188	719.2
ZB032398A	00563328	6	1.93437	620,591	2.22223	1,379,093	1,379.1
ZB032398A	01123389	7	1.71941	559,204	1.36333	762,379	762.4
ZB032398A	01284087	8	1.56367	523,087	1.61963	847,207	847.2
ZB032398A	01422543	9	1.29821	430,505	1.06248	457,405	457.4
ZB032398A	01560683	10	1.44558	492,793	0.53583	264,053	264.1
ZB032398A	02125970	11	1.74185	658,607	0.10906	71,826	71.8
ZB032398A	02280160	12	1.98397	609,313	0.03084	18,788	18.8
ZB032398A	02454436	13	0.35750	132,544	0.72221	95,725	95.7
ZB032398A	02512299	14	0.38811	124,303	0.07777	9,667	9.7
ZB032398A	02591787	15	0.49567	106,781	0.55864	59,652	59.7
ZB032398B	03380035	1	0.73770	171,205	0.02634	4,510	4.5
ZB032398B	03425329	2	0.32014	102,044	0.07020	7,163	7.2
ZB032398B	03464060	3	0.54703	62,263	0.03946	2,457	2.5
ZB032398B	03501118	4	0.28776	42,479	0.09929	4,218	4.2
ZB032398B	03532962	5	0.44745	149,514	0.30869	46,154	46.2
ZB032398B	03565402	6	1.43772	397,794	0.15542	61,827	61.8
ZB032398B	04103033	7	1.24712	595,251	2.51445	1,496,731	1,496.7
ZB032398B	04273932	8	1.66382	788,957	4.99723	3,942,601	3,942.6
ZB032398B	04420961	9	1.78881	852,608	5.50397	4,692,727	4,692.7
ZB032398B	04574976	10	2.02147	943,242	1.44706	1,364,931	1,364.9
ZB032398B	05172301	11	1.39593	810,723	0.09299	75,391	75.4

Table 5. Estimated contribution by age class (tonnes) to the acoustic biomass and to the spawning acoustic biomass of pre-spawning herring by survey replicate based on acoustic surveys conducted by ADF&G personnel, Prince William Sound, Alaska, spring 1998.

Biomass Type	Major Area	Survey Stratum	Begin Date	Survey Code	Age 2	3	4	5	6	7	8	9+	Acoustic Biomass tonnes	Variance
Acoustic Biomass	Montague	Zaikof Bay	3/23/98	ZB032398A	6	1,326	2,084	710	861	73	265	818	6,144	2.55E+08
			3/23/98	ZB032398B	11	2,526	3,968	1,353	1,640	140	505	1,557	11,699	2.92E+09
		Stockdale Hbr	3/24/98	SH032498A	3	614	835	246	351	36	125	572	2,782	4.59E+09
			3/24/98	SH032498B	2	467	635	187	267	27	95	435	2,116	2.47E+07
		Rocky Bay	3/25/98	RB032598A	-	-	-	-	-	-	-	-	-	
			3/25/98	RB032598B	6	604	986	283	346	55	97	475	2,852	4.10E+08
			3/25/98	RB032598C	3	301	491	141	172	28	48	236	1,421	3.38E+07
	East	Knowles Head	3/27/98	KH032798A	-	135	474	132	156	25	78	192	1,192	3.43E+06
Average Acoustic Biomass	Montague	Zaikof Bay	3/23/98		8	1,926	3,026	1,031	1,251	106	385	1,187	8,921	
		Stockdale Hbr	3/24/98		3	541	735	216	309	32	110	504	2,449	
		Rocky Bay			4	452	739	212	259	41	73	355	2,136	
	East	Knowles Head			-	135	474	132	156	25	78	192	1,192	
Spawning Recruitment at Age (from ASA)					0	0.26	0.85	1.00	1.00	1.00	1.00	1.00		
Spawning Acoustic Biomass	Montague	Zaikof Bay	3/23/98		-	508	2,584	1,031	1,251	106	385	1,187	7,053	
		Stockdale Hbr	3/24/98		-	143	628	216	309	32	110	504	1,941	
		Rocky Bay	3/25/98		-	119	631	212	259	41	73	355	1,691	
	East	Knowles Head	3/27/98		-	36	405	132	156	25	78	192	1,024	

Table 6. Estimated contribution by age class (tonnes) to the acoustic biomass and to the spawning acoustic biomass of pre-spawning herring by survey replicate based on acoustic surveys conducted by PWS Science Center personnel, Prince William Sound, Alaska, spring 1998.

Biomass Type	Major Area	Survey Code	Date	Location	Age 2	3	4	5	6	7	8	9+	Acoustic Biomass (tonnes)
Acoustic Biomass	Montague	h9801	3/23/98	Rocky Bay	5	585	955	274	335	54	94	459	2,761
		h9802	3/23/98	Rocky Bay	9	1,021	1,669	479	586	94	164	803	4,825
		h9803	3/23/98	Rocky Bay	12	1,254	2,049	588	719	115	201	986	5,924
		h9804	3/24/98	Stockdale Hbr	1	187	254	75	107	11	38	174	847
		h9805	3/24/98	Stockdale Hbr	1	121	165	49	69	7	25	113	550
		h9806	3/25/98	Zaikof Bay	9	2,065	3,245	1,106	1,341	114	413	1,273	9,567
		h9807	3/25/98	Zaikof Bay	7	1,609	2,528	862	1,045	89	322	992	7,454
	East	h9808	3/26/98	St. Matthews	-	118	414	115	136	22	68	167	1,041
		h9809	3/27/98	Sheep Bay	-	31	110	31	36	6	18	44	276
Peak Acoustic Biomass	Montague		3/23/98	Rocky Bay	12	1,254	2,049	588	719	115	201	986	5,924
			3/24/98	Stockdale Hbr	1	187	254	75	107	11	38	174	847
			3/25/98	Zaikof Bay	9	2,065	3,245	1,106	1,341	114	413	1,273	9,567
	East		3/26-27/1998	Eastern Total	-	149	524	146	172	28	86	212	1,317
Spawn Recruitment at Age (from ASA):					0	0.26	0.85	1.00	1.00	1.00	1.00	1.00	
Spawning Acoustic Biomass	Montague		3/23/98	Rocky Bay	-	331	1,749	588	719	115	201	986	4,690
			3/24/98	Stockdale Hbr	-	49	217	75	107	11	38	174	671
			3/25/98	Zaikof Bay	-	545	2,771	1,106	1,341	114	413	1,273	7,564
	East		3/26-27/1998	Eastern Total	-	39	447	146	172	28	86	212	1,130

Table 7. Average total acoustic biomass and acoustic spawning biomass estimates in tonnes of pre-spawning herring based on acoustic surveysconducted by ADF&G and PWS Science Center in Prince William Sound, Alaska, spring 1998. Shading indicates surveys summed to estimate acoustic biomass for major geographic areas (Montague Island and PWS total).

Survey Date	Acoustic Biomass (tonnes)							
	ADF&G Surveys			PWSSC Surveys			Total	
	Location	Total	Spawning	Location	Total	Spawning	Total	Spawning
3/23/98	Zaikof Bay	8,921	7,053	Rocky Bay	5,924	4,690	14,845	11,743
3/24/98	Stockdale Harbor	2,449	1,941	Stockdale Harbor	847	671	2,449	1,941
3/25/98	Rocky Bay	2,136	1,691	Zaikof Bay	9,567	7,564	11,703	9,255
3/23-25/98	Montague Island Total						17,294	13,683
3/26-27/98	Knowles Head	1,192	1,024	St. Matthews/Sheep Bays	1,317	1,130	2,509	2,154
3/23-27/98	PWS Total						19,804	15,837

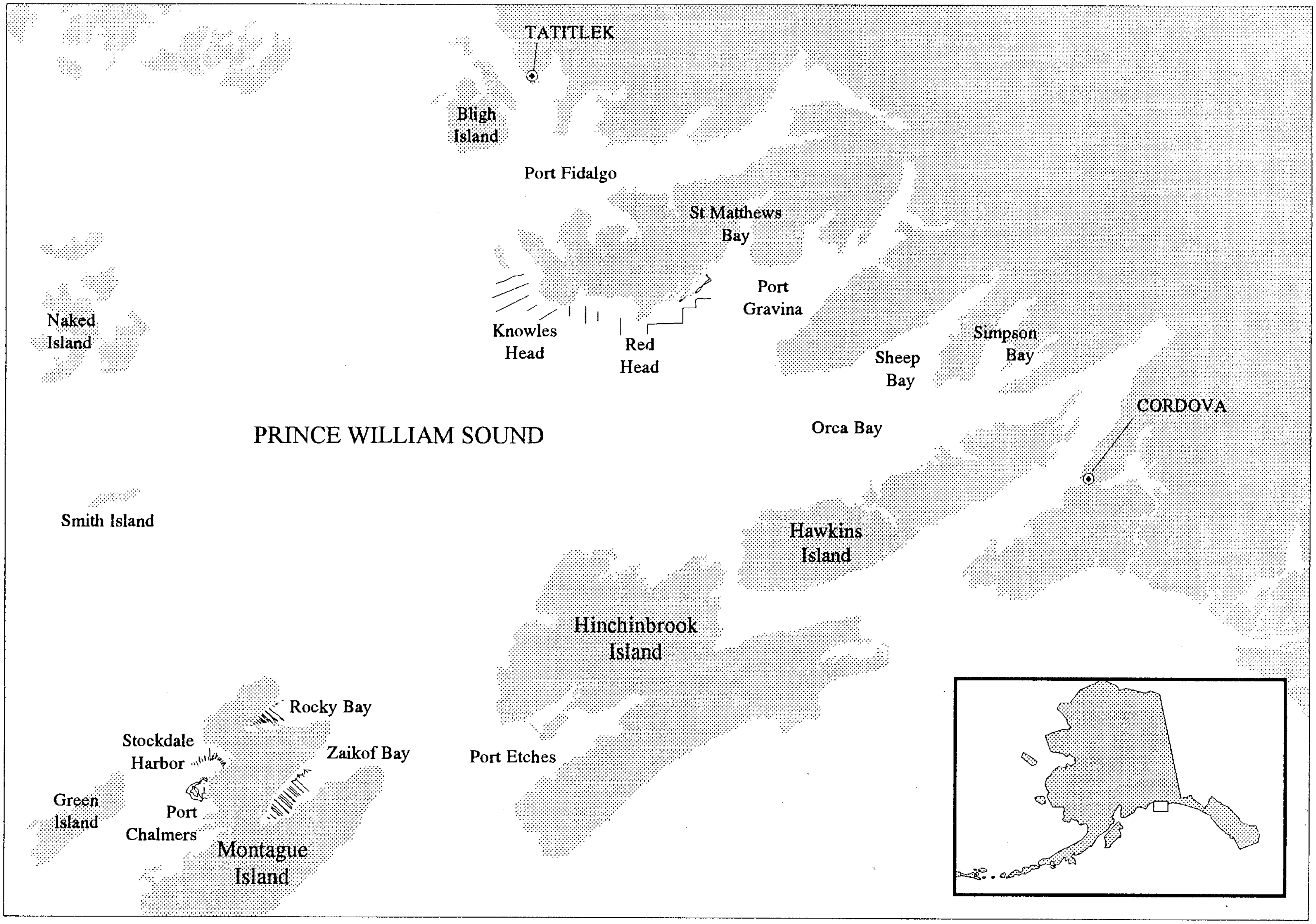

Figure 1. Acoustic survey locations for pre-spawning herring surveys conducted by ADF&G in Prince William Sound, Alaska, 1998.

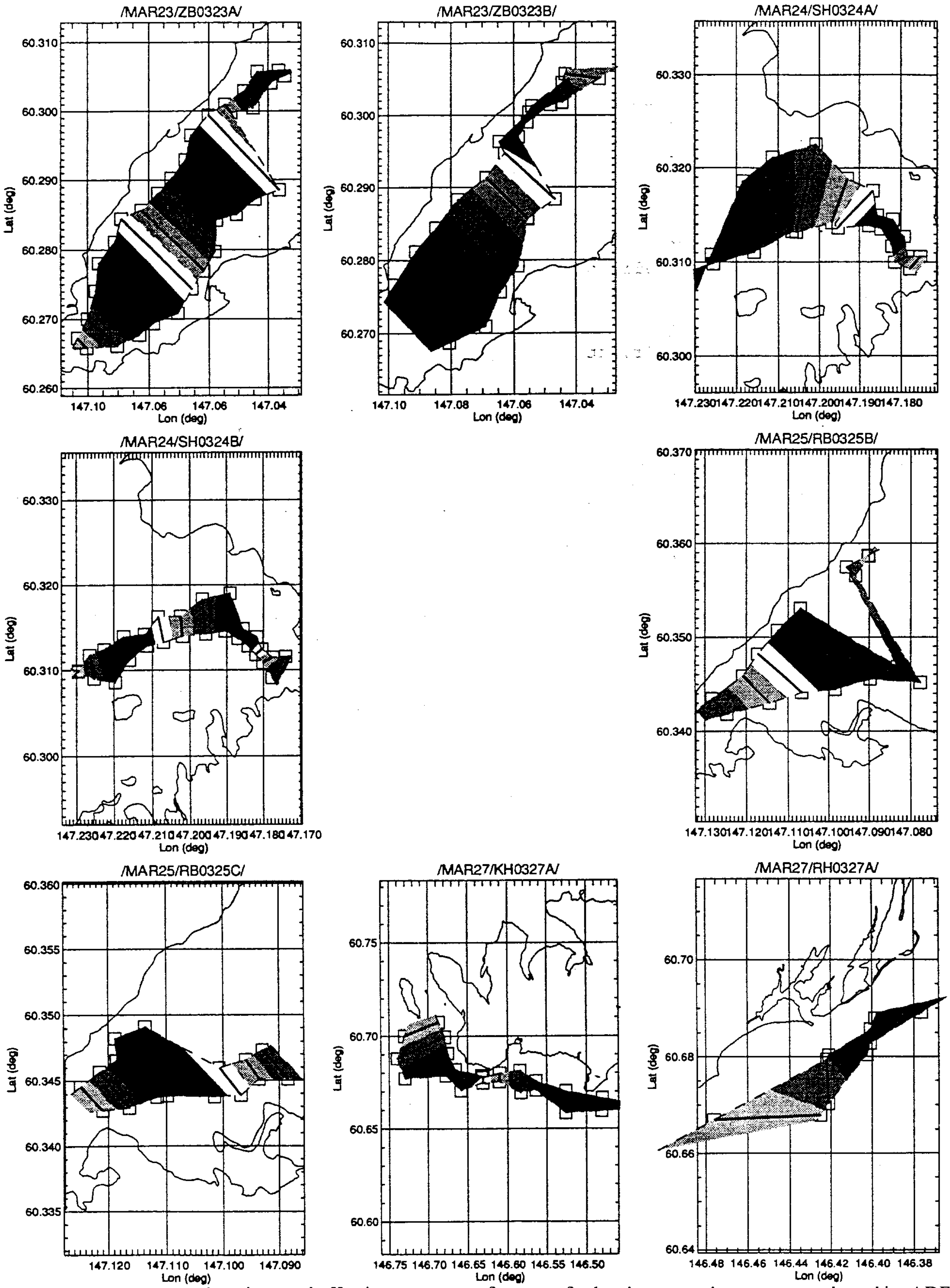

Figure 2. Transect locations and effective transect surface area for herring acoustic surveys conducted by ADF&G personnel, Prince William Sound, Alaska, 1998.

Appendix A.

Acoustic biomass estimate of adult herring in Prince William Sound, Alaska, in spring 1998. Prince William Sound Science Center, Final Report to Alaska Dept. Fish and Game, July 30, 1998.

Introduction

The use of acoustics for stock assessment of schooling fishes has received widespread acceptance by the international fisheries science community (MacLennan and Simmonds 1992, Thomas 1992). Acoustic surveys of Pacific herring (*Clupea pallisi*) have been conducted for several years in Prince William Sound (DeCino et al. 1994, Thomas et al. 1995, Kirsch and Thomas 1997). Recently, acoustic-purse seine surveys of herring in Prince William Sound have shown the ability to make repeatable estimates that allow tracking of the changes in herring population size over time (Thomas et al. 1997).

The objective of this study was to estimate the size of the herring stock spawning in Prince William Sound in 1998. The acoustic survey was conducted simultaneously with widespread aerial surveys and underwater sonar searching, which located the largest available spawning aggregations. All the survey effort described in this report took place between March 23 and 27, 1998. During that time, the bulk of the pre-spawning herring were highly aggregated in Rocky and Zaikof Bays on the northeast corner of Montague Island. The aerial surveys and sonar searches in other areas did not reveal other large concentrations at this time.

Field Acquisition Methods

This survey covered the northern Montague Island and the central-eastern regions of the Sound using the purse seiner *F/V Miss Kayley*. We used a BioSonics 120kHz 101 scientific echosounder with a pre-amped dual-beam transducer mounted on a BioSonics 1.2 m BioFin, BioSonics Echo Signal Processor (ESP) software for real-time echo-square integration, a Magellan DLX-10 GPS receiver for georeferencing the data, a digital audio tape (DAT) recorder for signal backup, and a chart recorder for high resolution paper echograms.

Echosounder system parameters were set to a source level (SL) of 225.023 dB re µPa, and a receiver gain (RG) of -165.282 dB re V. A standard target calibration was conducted after the cruise to verify these values. The pulse duration was 0.4 msec and the beam pattern factor 0.00107, which when combined with the system parameters, yield an equipment constant k_{equip} of 1891.0 to be used in the echo-integrator (Ehrenberg and Lytle 1972). The trigger interval was 0.5 sec (2 pings/sec). The threshold on the echo-integrator was set to 0.1 V, resulting in a minimum measurable S_v of -52.8 dB, or approximately 0.008 kg/m^3. The maximum range of the sonar was set to 60 meters, as prespawning herring in six previous surveys (1993-1997) were not found deeper than 60 m.

A multi-stage survey design was used to assess the population. First, an area where herring historically reside was chosen, based on local fishermen's knowledge and past experience. Aerial surveys confirmed the presence of fish in these areas. Fish aggregations in these areas were mapped out using the survey vessel's scanning sonar. Then using the scientific echosounder, closely spaced parallel or zig-zag transects were run over the aggregation, typically perpendicular to the bottom contours.

Table 1 describes the 9 acoustic surveys that were conducted, including all repeat surveys of the Rocky, Stockdale, and Zaikof areas. Figure 1 shows the tracklines of the boat for all of the acoustic surveys. Each survey consisted of between 3 and 20 transects (xs), depending on the size and the fish density of the area surveyed.

Table 1. Acoustic survey descriptions

#	Date	Time Begin	Time End	N xs	Design	Location
01	3/23	2112	2204	7	parallel	Rocky Bay
02	3/23	2214	2334	11	parallel	Rocky Bay
03	3/24	0025	0136	10	parallel	Rocky Bay
04	3/24	2102	2300	14	zig-zag	Stockdale Harbor
05	3/24	2334	0032	11	zig-zag	Stockdale Harbor
06	3/25	2053	2317	15	parallel	Zaikof Bay
07	3/25	2340	0132	16	parallel	Zaikof Bay
08	3/26	2255	0055	20	zig-zag	St. Matthews Bay
09	3/27	2140	2218	3	zig-zag	Sheep Bay

Seine sets (n=6), using a 10-f deep by 120-f long purse seine, were used to identify acoustic targets (Table 2). Sampling and processing were performed by ADF&G, who recorded lengths, weights, and ages in the laboratory after the cruise. The equivalent target strengths (TS_w) were then calculated using Thorne (1983).

Table 2. Seine catch and descriptions

#	Date	Time	Length (mm)	TS_w (Thorne)	Surveys represented	Location
1	3/23	1900	208	-32.1	01,02,03	Rocky Bay
2	3/24	0205	194	-31.9	01,02,03	Rocky Bay
3	3/24	1900	201	-32.0	04,05	Stockdale Harbor
4	3/24	2000	214	-32.2	04,05	Stockdale Harbor
5	3/26	0215	209	-32.1	06,07	Zaikof Bay
6	3/27	0145	210	-32.1	08,09*	St. Matthews

* Extrapolation

Processing and analysis methods

Raw acoustic data was processed and analyzed using in-house software that applied calibrations and target strengths, calculated transect size and survey surface areas, allowed the user to interactively classify layers, estimated biomass density and abundance, and created color maps of the surveys.

Temperature and salinity profiles were measured in mid-March 1998 by the physical oceanography component of the SEA project (Vaughan et al. 1997) using a Seabird 19 CTD lowered from the surface to within a few meters from the botttom. These data indicate the average water temperature over all depths to be 5.6 deg C, and the average salinity to be 31.5 ppt in the Zaikof Bay area (Vaughan, pers comm). These values result in an absorption value of $\alpha = 0.030$ dB/m at 120 kHz (Medwin and Clay 1998). Since the echosounder assumes an absorption value of 0.0347 dB/m, an additional TVG algorithm was applied to the echo-integration arrays during post-processing, so that 20LogR + 2(.030)R was applied for all depths in the arrays.

Calculation of absolute density requires knowledge of the backscattering cross-section (σ) of the individual targets, which is the arithmetic equivalent of target strength (TS). TS with respect to weight (TS_W) was predicted using the equation developed by Thorne (1983),

$$TS_W = 5.98Log_{10}(Length(mm)) - 24.234 \quad (dB_{Kg})$$

For each seine set, the backscattering cross section over weight (σ/w) was calculated and averaged to yield a target constant for each net. Biomass density was calculated by multiplying the acoustic backscatter (echo-square integration with calibrations applied) by the reciprocal of this target constant,

$$Biomass\ density = \frac{V^2}{k_{equip}}\left(\frac{w}{\sigma}\right)$$

Average density (in kg/m^2) was determined by summing the 32-ping cells from the surface to 60 m (or bottom, if shallower). We assumed each acoustic report (32 pings) was of the same spatial size, since boat speed was constant within each transect. Averages and confidence limits for each survey were calculated (Seber 1973, Cochran 1977) by weighting these densities by each transect's effective surface area (determined by the GPS transect coordinates), which can differ from transect length when the transect spacing is not uniform. Survey surface area was determined by algorithmically connecting the endpoints of the transects in the survey, and calculating the area of the filled polygon. Multiplying the average biomass density of the survey by the surface area yields absolute abundance in tonnes.

Results

The seine catches were 100% herring, so the acoustic backscatter arrays did not need compensating for other species. The average size of the herring varied slightly with location (Figure 2), with the smallest fish found in Rocky Bay ($\bar{l}$ = 197 mm, $\bar{w}$ = .102 kg), and the larger fish found in Zaikof and Stockdale ($\bar{l}$ = 208, $\bar{w}$ = 0.120 kg). The catch was a mix of sub-adults and adults, so additional work will be needed to break the acoustic biomass values into those age components. The numerical proportions must be multiplied by the average weights to yield biomass proportions of immature and mature herring.

Large aggregations of herring were found primarily in Rocky and Zaikof Bays. Reconnaissance found very few fish in Port Chalmers, so that area was not surveyed. Table 3 lists the densities, survey area sizes, and abundances, with their confidence limits. The biomass totaled 17,655 ± 3,578 metric tonnes. In the areas where there were over 4,000 metric tons, the 2-3 repeated estimates ranged from 12% to 39% of the mean.

Geographical distributions (Figures 3-11) generated for the nine surveys show that herring can aggregate in the middle of a bay or against the shore. Depth distributions (Figure 12) generated for each survey indicate that herring are typically located between the surface and 60 meters, with the peak concentration between 10 meters and 40 meters deep.

Table 3. Biomass estimates

#	Biomass Density (T/NM^2)	+/- 95%	Surface Area (NM^2)	Biomass (Tonnes)	+/- 95%	Location
01	6,671	2,823	0.414	2,761	1,169	Rocky Bay
02	10,217	2,007	0.472	4,825	948	Rocky Bay
03	12,316	2,582	0.481	* 5,924	1,242	Rocky Bay
04	771	131	1.100	* 847	144	Stockdale Harbor
05	1,670	323	0.329	550	106	Stockdale Harbor
06	7,740	1,641	1.240	* 9,567	2,028	Zaikof Bay
07	7,972	1,163	0.886	7,454	1,114	Zaikof Bay
08	497	27	2.090	* 1,041	57	St. Matthews Bay
09	141	54	1.960	* 276	107	Sheep Bay

* Maximums used in total

Discussion

Sources of decrease from last year's biomass

Our 1998 estimates of herring abundance were much lower than our estimates for 1997 (37,400 T). There are several explanations that may account for this difference: 1997 commercial herring harvest, age composition differences, school truncation, natural and anthropogenic mortality, and reduced survey coverage.

In Spring 1997 there was a herring fishery, where 4,690 tonnes were harvested. In fall

1997, there was a food and bait fishery that harvested 524 metric tonnes of herring. Adding 5,214 tonnes to our current 1998 estimate falls short of the 1997 population, suggesting that mortality exceeded recruitment in 1997.

The age distribution from the net catches has not been applied, so these estimates include both sub-adult and adult herring. Although the catch data has not been fully analyzed, visual observations indicated the catch this year to have older fish than last year, as there were many sub-adults caught during the 1997 survey. This effectively reduces the 1997 adult estimate. This issue will be resolved after ADF&G conducts cohort analysis.

The major sources of variation in our estimates of biomass for an area come from fish movement. Most all of the herring concentrations are found associated with steep and rugged shorelines. In these areas the fish display constant movement often moving to and from the shoreline. When the herring move too close to shore, the survey vessel cannot sample adequately and the measurement of the fish concentration is truncated (Thomas et al. 1997). Truncated surveys are not valid replicates and may need to be discarded. This appears to be the case in Rocky Bay, where high concentrations of fish are seen at the north ends of the transects. For the cases where truncation is obvious, we used the survey with the highest biomass estimate in determination of total abundance, although the highest biomass estimate may still be suspect.

Coverage of PWS was reduced for this survey, due to the cruise being shorter in duration in 1998 than in 1997. These estimates do not include fish west of Red Head and in Port Fidalgo, which was covered by the R/V Montague. It is also possible that the warmer temperatures this year could have had an impact on the fish behavior, moving them to regions we did not survey.

Changes from the preliminary report

These values differ from those reported in the preliminary report of May 1998 (22,154 T). This is due to weighting the individual transect densities by their effective surface areas instead of their lengths, since transect spacing was not always constant during these surveys. Transects were occasionally spaced closer together in higher density areas during these surveys, which results in an over-estimate of biomass. This is especially the case in survey 06 (Zaikof, Figure 8), which decreased from 12,990 T to 9,567 T. In 1997, transect weighing was based on transect length, however the transect spacing was more uniform that year.

In survey 07 (Zaikof), a small part of a herring school was mis-tracked as bottom. To fix this, the bottom was reconstructed in those reports. This increased the biomass estimation for that survey from 6,902 to 7,454 tonnes.

General sources of error

Common sources of error in acoustic estimates include TS fluctuation, extinction, and bottom/boundary interference.

The target strength (TS) used to scale acoustic backscatter to biomass density is based on an acoustic scattering model, which requires accurate length information. This requires that the seine sets catch an accurate representation of the sizes. Figure 13 shows the effects of applying erroneous length to the Thorne model. Also, there is a discrepancy in TS estimation between Foote (1987) and Thorne (1983), which could mean that we are underestimating biomass by 50%. This issue will be addressed in a 1999 EVOSTC research contract.

Another source of error, that results in a possible underestimation, is extinction of sound by the school (Foote 1990). Dense fish schools can attenuate sound waves, and result in less backscatter. This effect is worse with shallower fish since the beam is smaller and more interceptible near the transducer, and with denser schools. Until more research has been done to quantitatively investigate the amount of absorption, it is usually assumed that multiple scattering (reverberation) compensates for most of this loss.

A final source of error is mistracking of bottom. Bottom was occasionally mis-tracked and integrated with the fish data in surveys 04 (transects 10 and 14) and 05 (transect 6). However, this bottom was removed through a graphical editor in the post-processing stage. In survey 07, a small part of the school was mis-tracked as bottom. For those suspected transects, the bottom was redefined so that the fish data remained intact and separate, thus correcting any error in biomass estimation due to bottom mistracking.

Sources of variability within a survey area

Two major sources of variation in our measurements of fish density are from the non-uniform distribution of the fish within the survey area, and from the non-uniform internal density of the fish school. These sources of error are reduced at night, when the vertical distribution of the fish is stable and in mid-water, and school densities are not too high. As long as the fish are not too close to a boundary (surface, shore, or bottom), we have found the estimates of biomass for large concentrations of fish (>5 thousand metric tonnes) in an area to be repeatable.

Figures

Acknowledgements

Jack Babic and the crew of the *F/V Miss Kayley* are thanked for their support. John Wilcock helped organize the cruise logistics, and provided information from the seine sets. Cece Stack assisted with the net samples. Nick Peters and Geoff Steinhart assisted with the calibration of the acoustic gear. This work was supported by ADF&G through contract IHP-98-037.

References

Cochran, William G. 1977. Sampling Techniques. John Wiley & Sons. New York. New York. 428 pp.

DeCino, Robert, J. Wilcock, E. V. Patrick, R. E. Thorne and G. L. Thomas. 1994. Acoustic estimate of the Herring biomass in the Green Island area of the Prince William Sound, Alaska. Technical Report. Prince William Sound Science Center. 15 pp.

Ehrenberg, J. E. and D. W. Lytle. 1972. Acoustic techniques for estimating fish abundance. Transactions of Geoscience Electronics. 10: 138-145.

Foote, K. G. 1987. Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am. 82: 981-987.

Foote, K. G. 1992. Correcting acoustic measurements of scatering density for extinction. J. Acoust. Soc. Am. 88:1543-1546.

Kirsch, J. and G. L. Thomas 1997. Acoustic biomass estimate of adult herring in Prince William Sound, Alaska, in Spring 1997. Report to ADF&G. 42pp.

MacLennan, D. N. and E. John Simmonds. 1992. Fisheries Acoustics. Chapman & Hall. London. 325pp.

Medwin, H. and C. S. Clay. 1998. Fundamentals of Acoustical Oceanography. Academic Press, San Digeo. 712 pp.

Seber, G. A. F. 1973. The estimation of animal abundance and related parameters. Charles Griffin and Co. London. 506pp.

Thomas, G. L. 1992. Successes and failures of fisheries acoustics --- an international, federal, and regional point of view. Fisheries Research. 14(2-3): 95-104.

Thomas, G. L., J. Kirsch, and J. Wilcock, 1995. Pacific Herring Biomass in the Knowles Head and Green Island Areas of Prince William Sound, Alaska, in the Fall of 1994. Report to ADF&G. 15 pp.

Thomas, G. L., E. V. Patrick, J. Kirsch, and J. R. Allen. 1997. Development of an ecosystem model for managing the fisheries resources of Prince William Sound. pp. 606-613. In Hancock, D.A., D.C. Smith, A. Grant, J. P. Beumer [eds.]. Developing and sustaining world fisheries resources, the state of science and management. 2nd World Fisheries Congress. CSIRO Australia.

Thorne, R. E. 1983. Assessment of population abundance by hydroacoustics. Biological Oceanography 2:253-262

Vaughan, S. L., S. M. Gay, L. B. Tuttle, and K. E. Osgood, 1997. SEA: Water Mass Variability and Circulation in Prince William Sound. *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 96320-M), Prince William Sound Science Center, Cordova, AK.

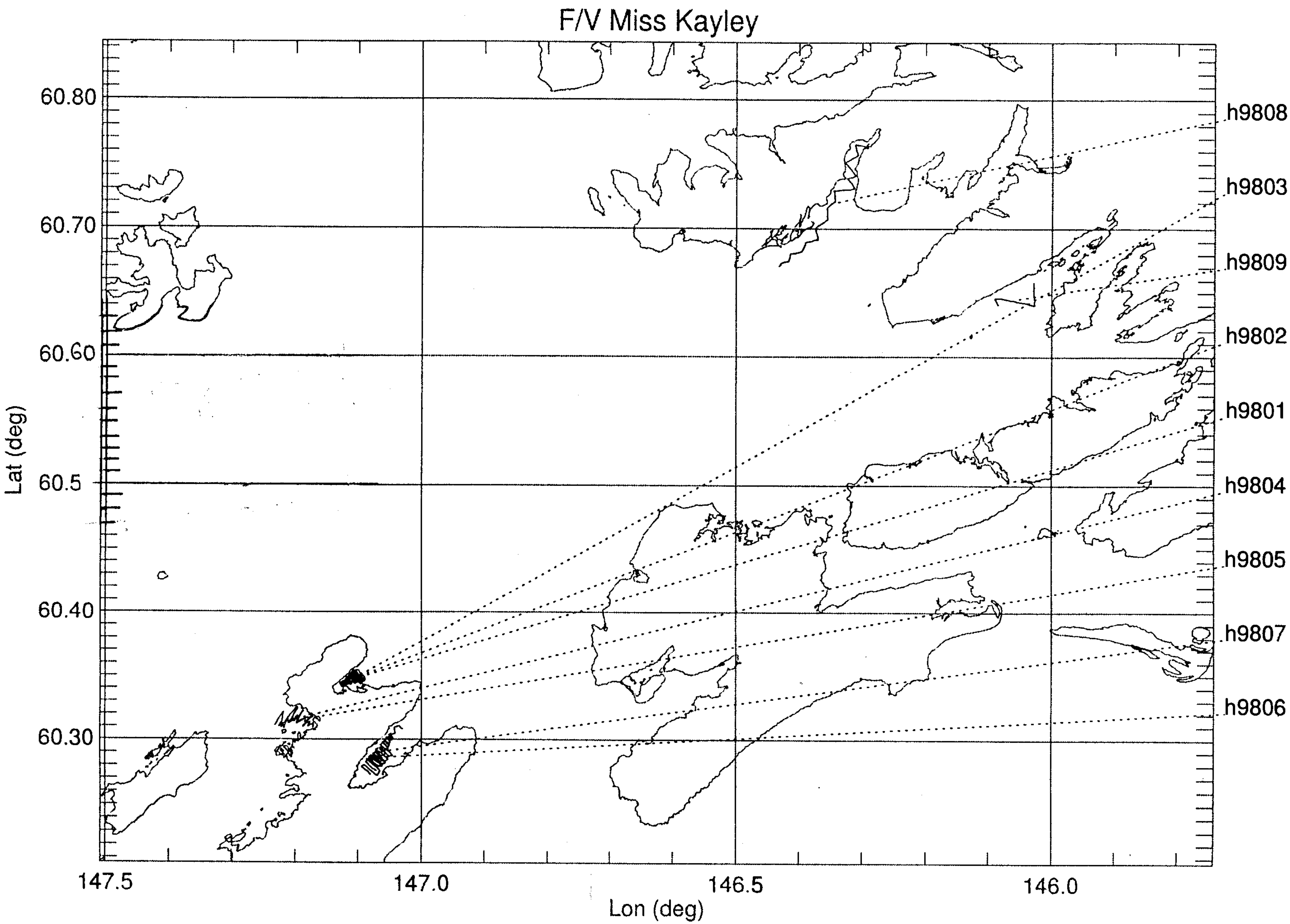

Figure 1. 1998 Herring acoustic surveys, with survey index (see Table 1)

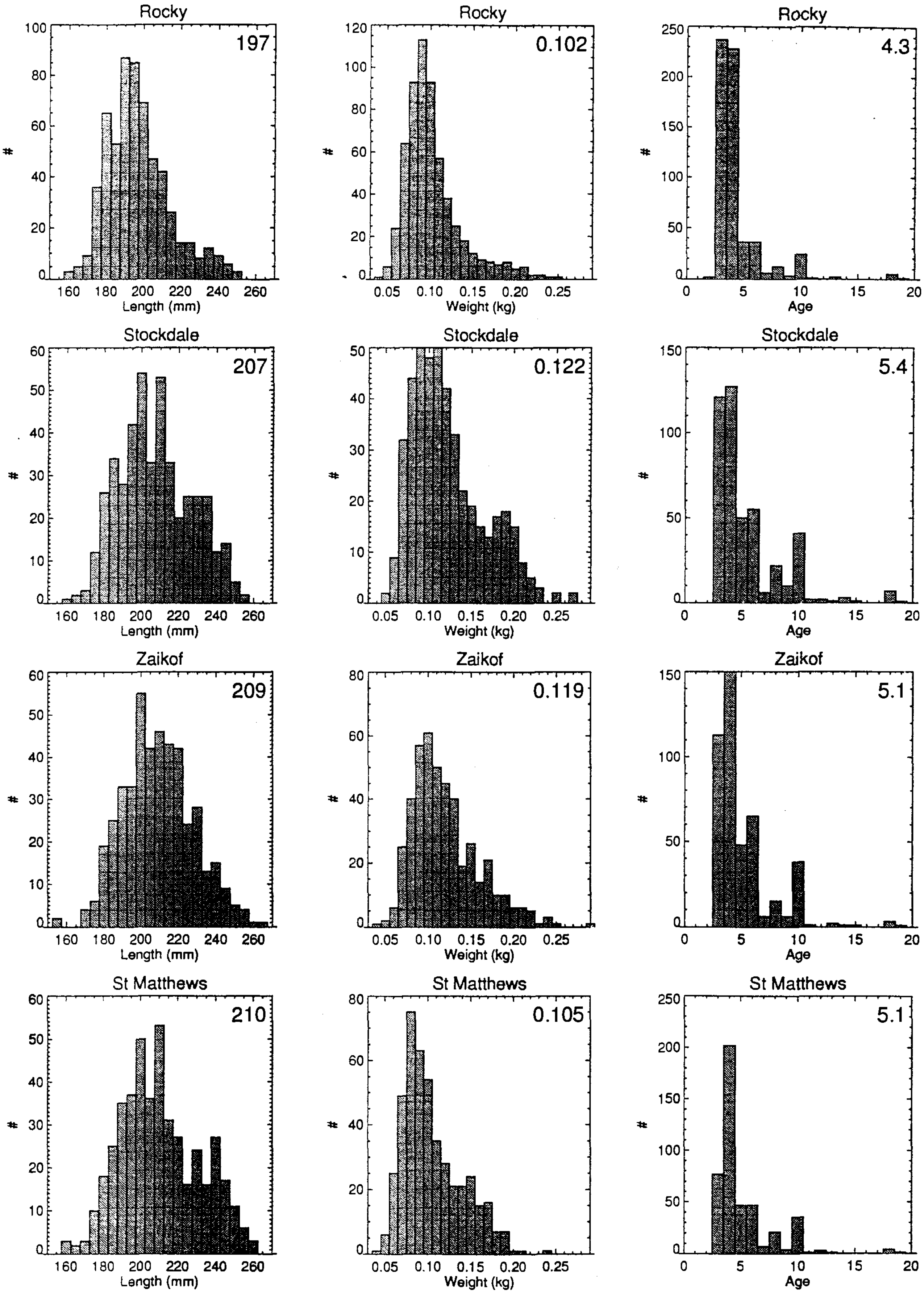

Figure 2. Herring size distributions from March 1998 Miss Kayley catch

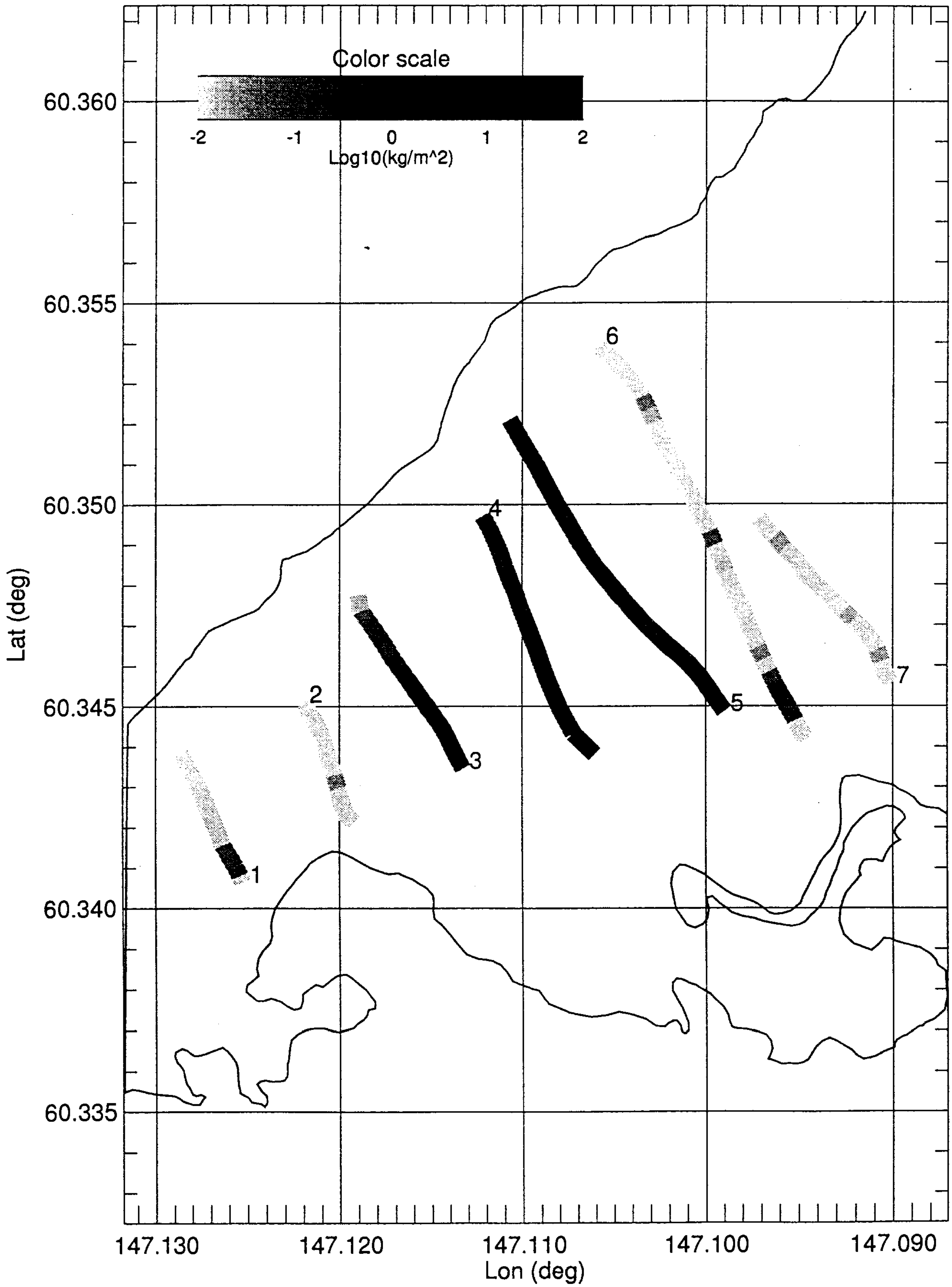

Figure 3. Rocky Bay (h9801) herring distribution

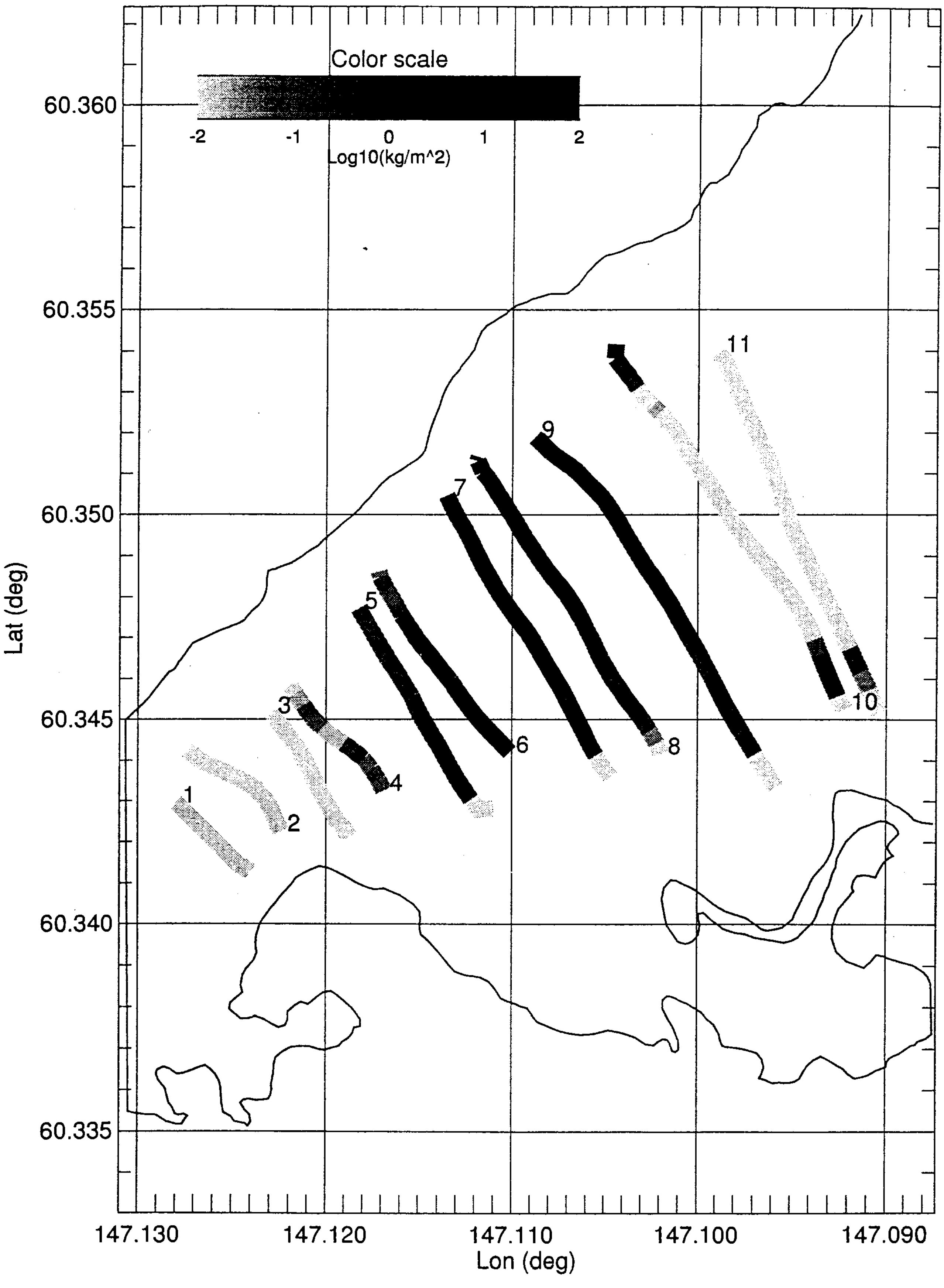

Figure 4. Rocky Bay (h9802) herring distribution

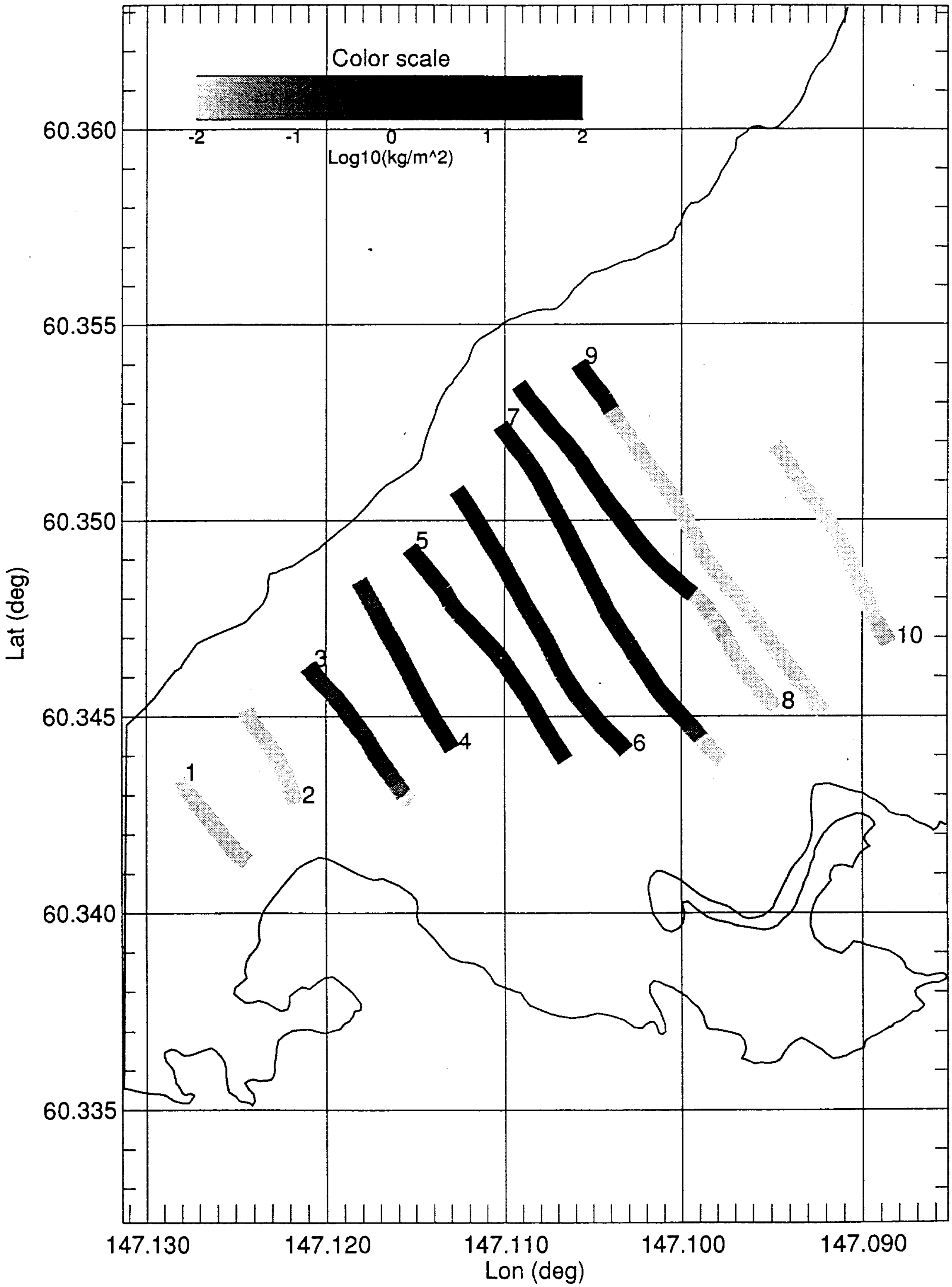

Figure 5. Rocky Bay (h9803) herring distribution

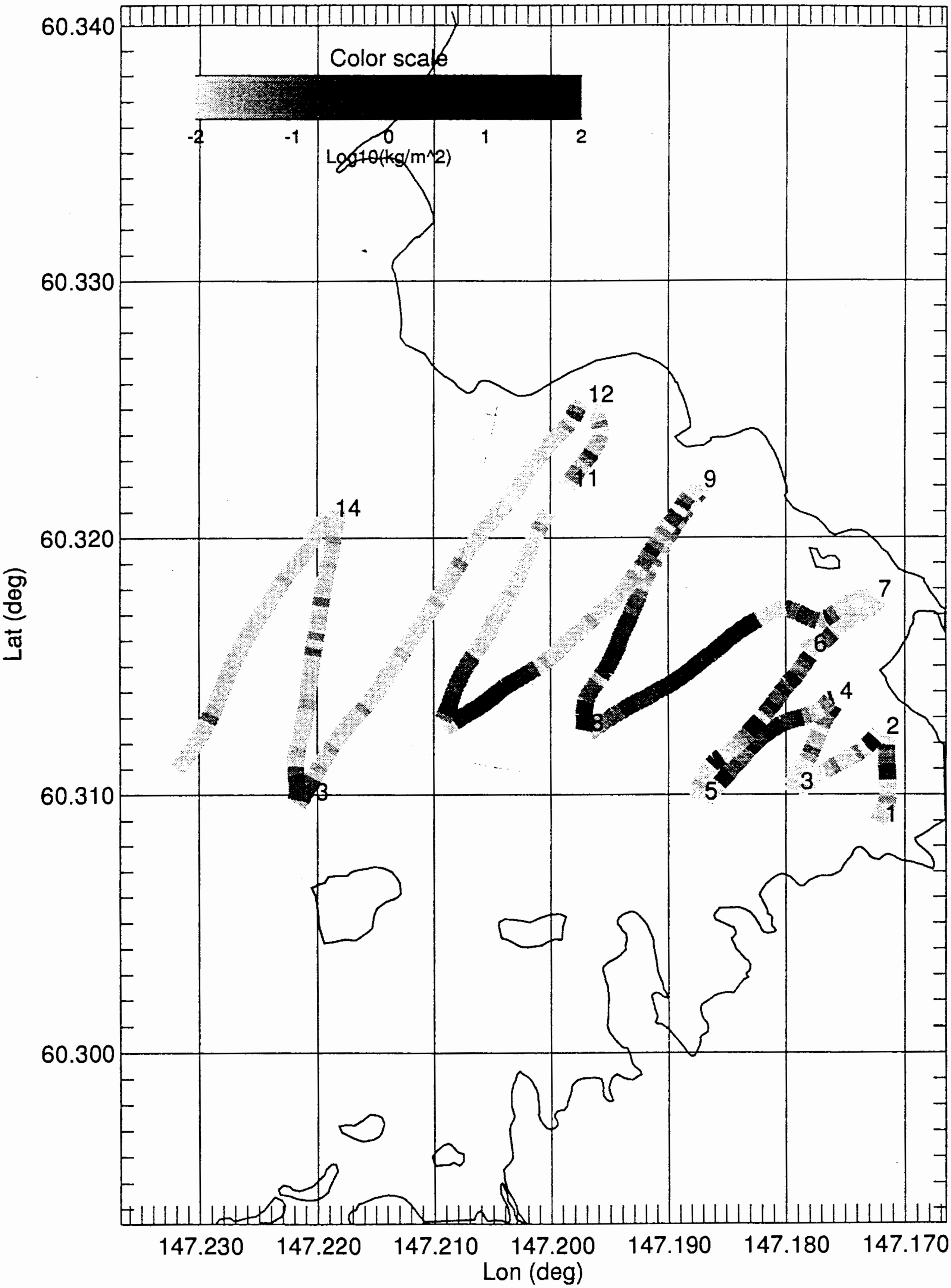

Figure 6. Stockdale (h9804) herring distribution

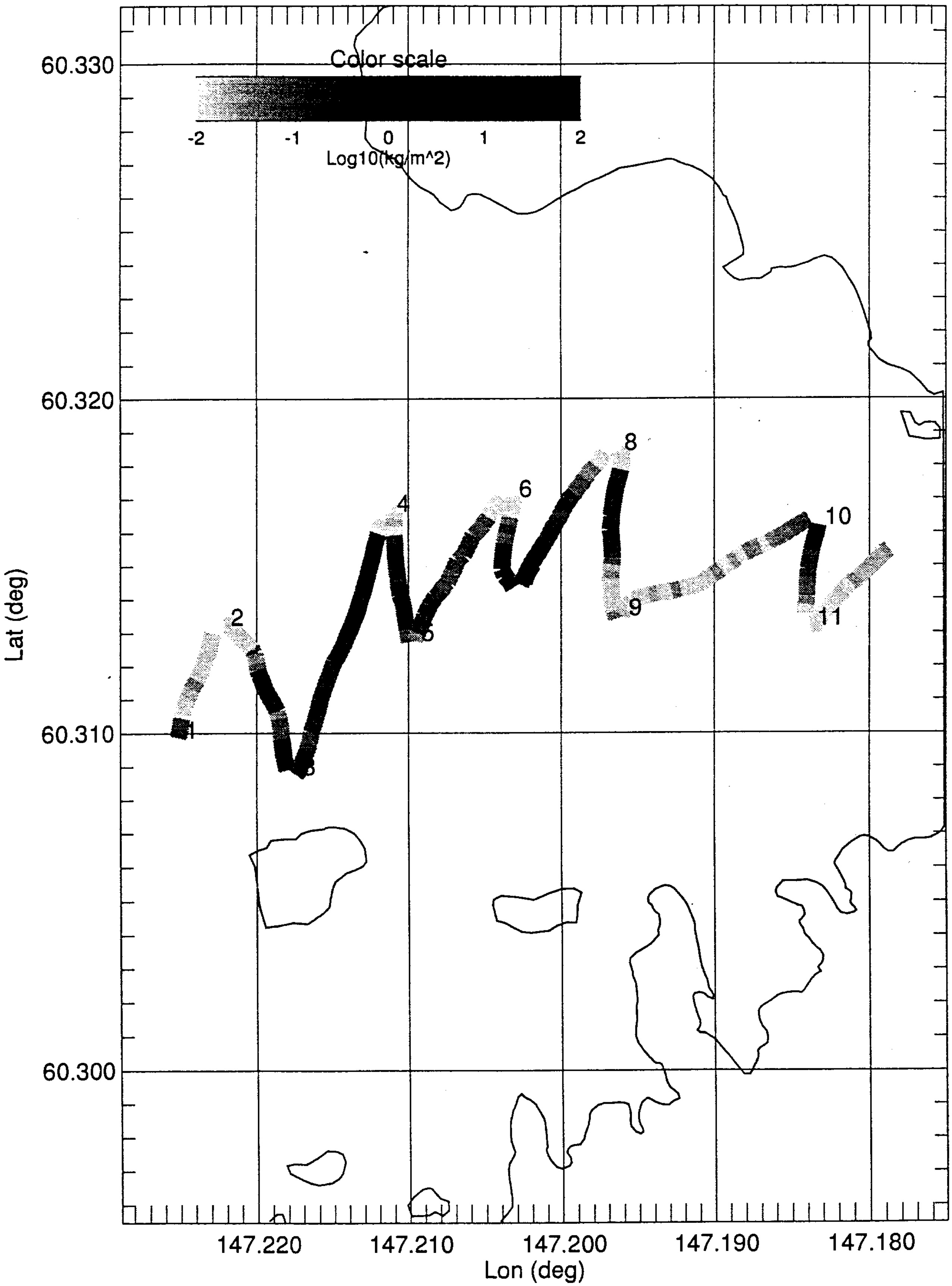

Figure 7. Stockdale (h9805) herring distribution

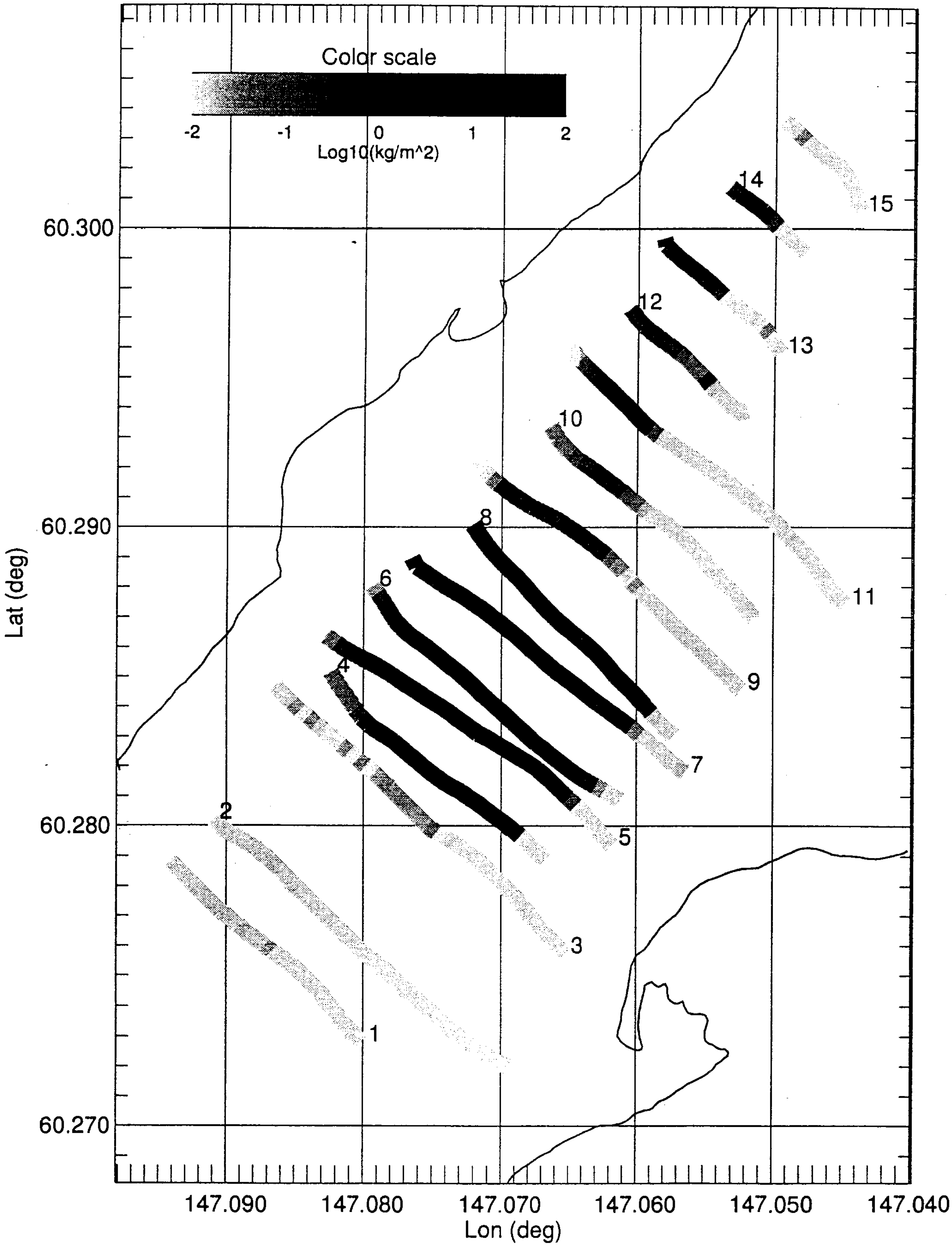

Figure 8. Zaikof Bay (h9806) herring distribution

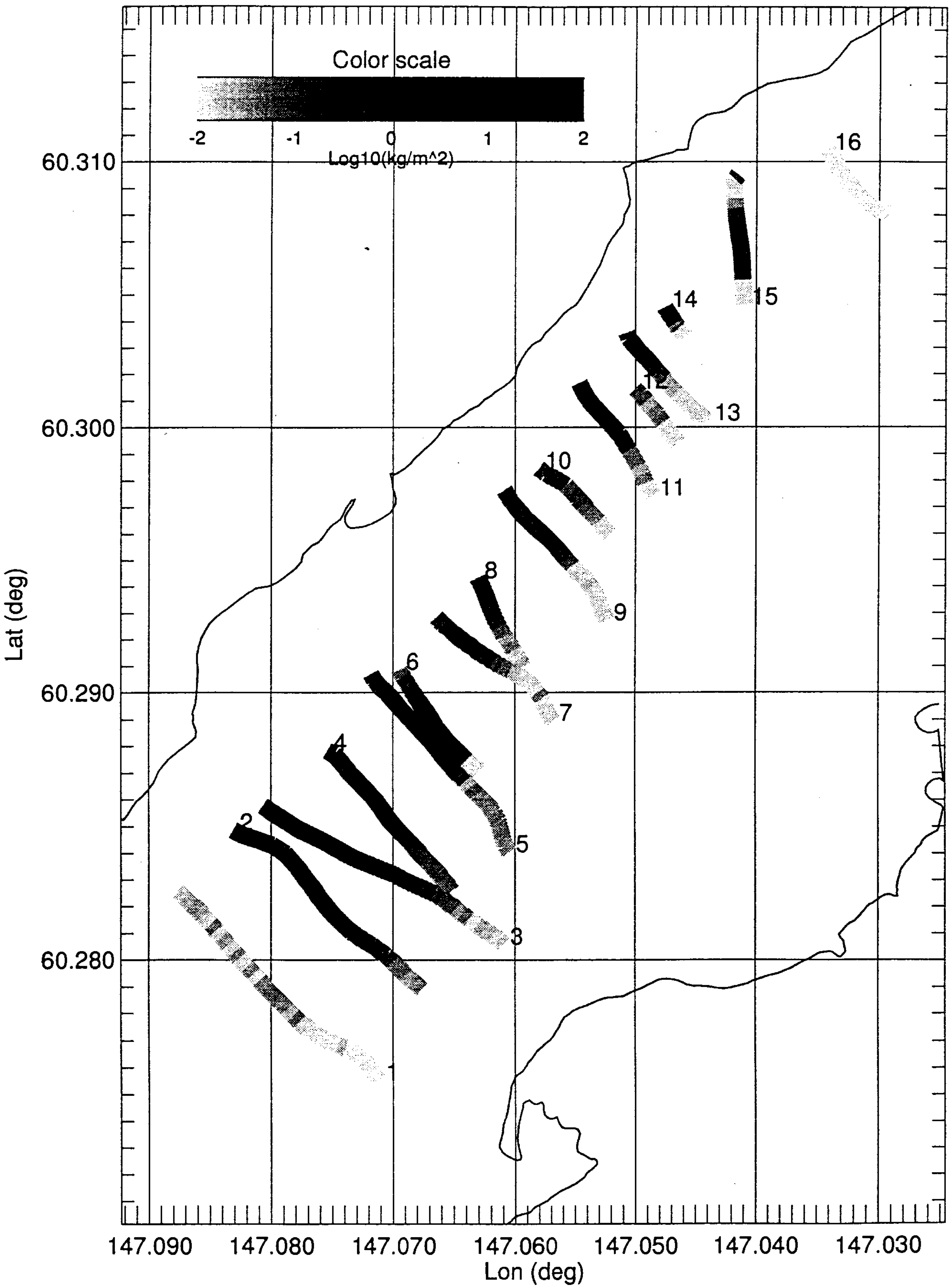

Figure 9. Zaikof Bay (h9807) herring distribution

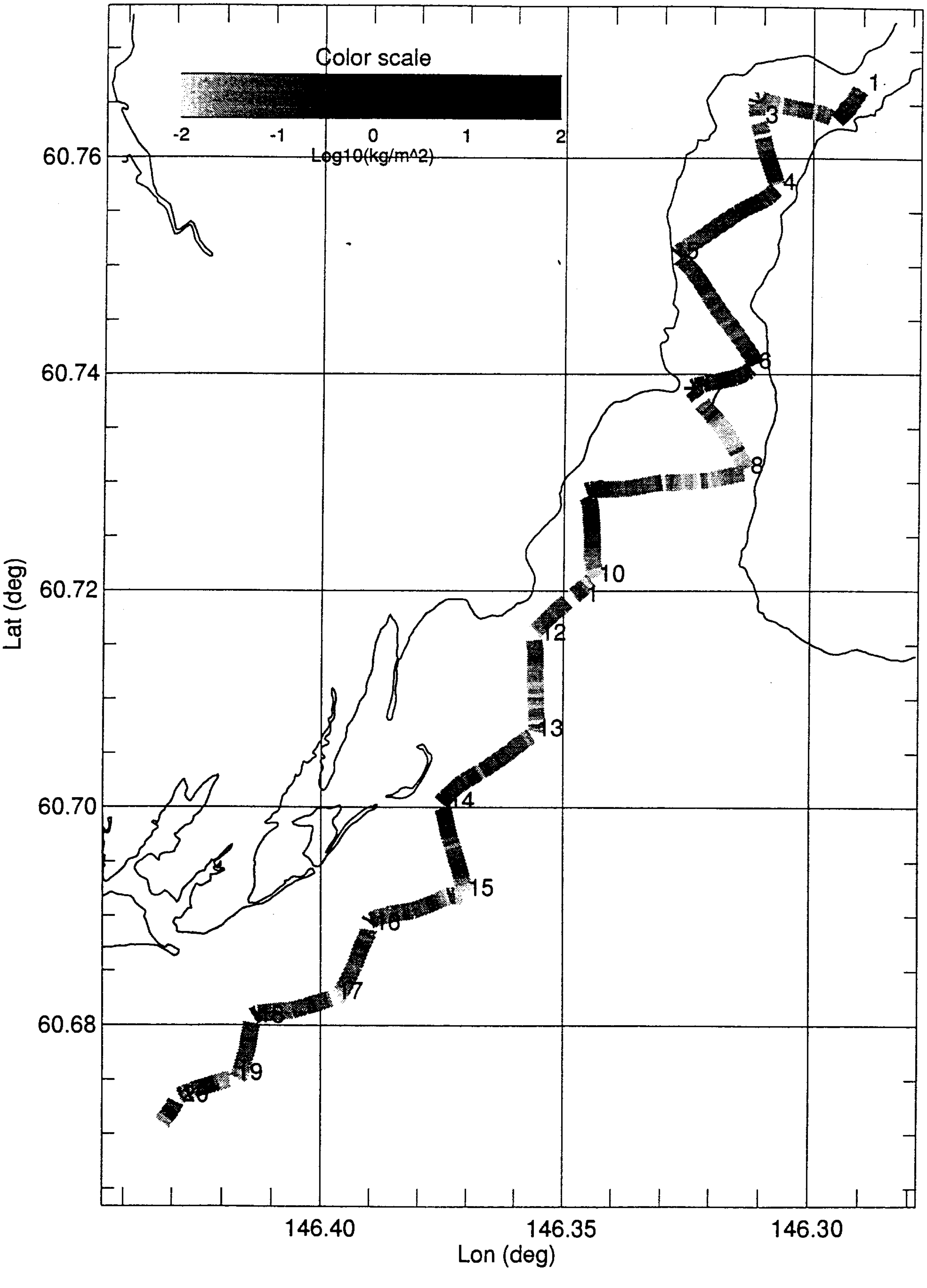

Figure 10. St. Matthews Bay (h9808) herring distribution

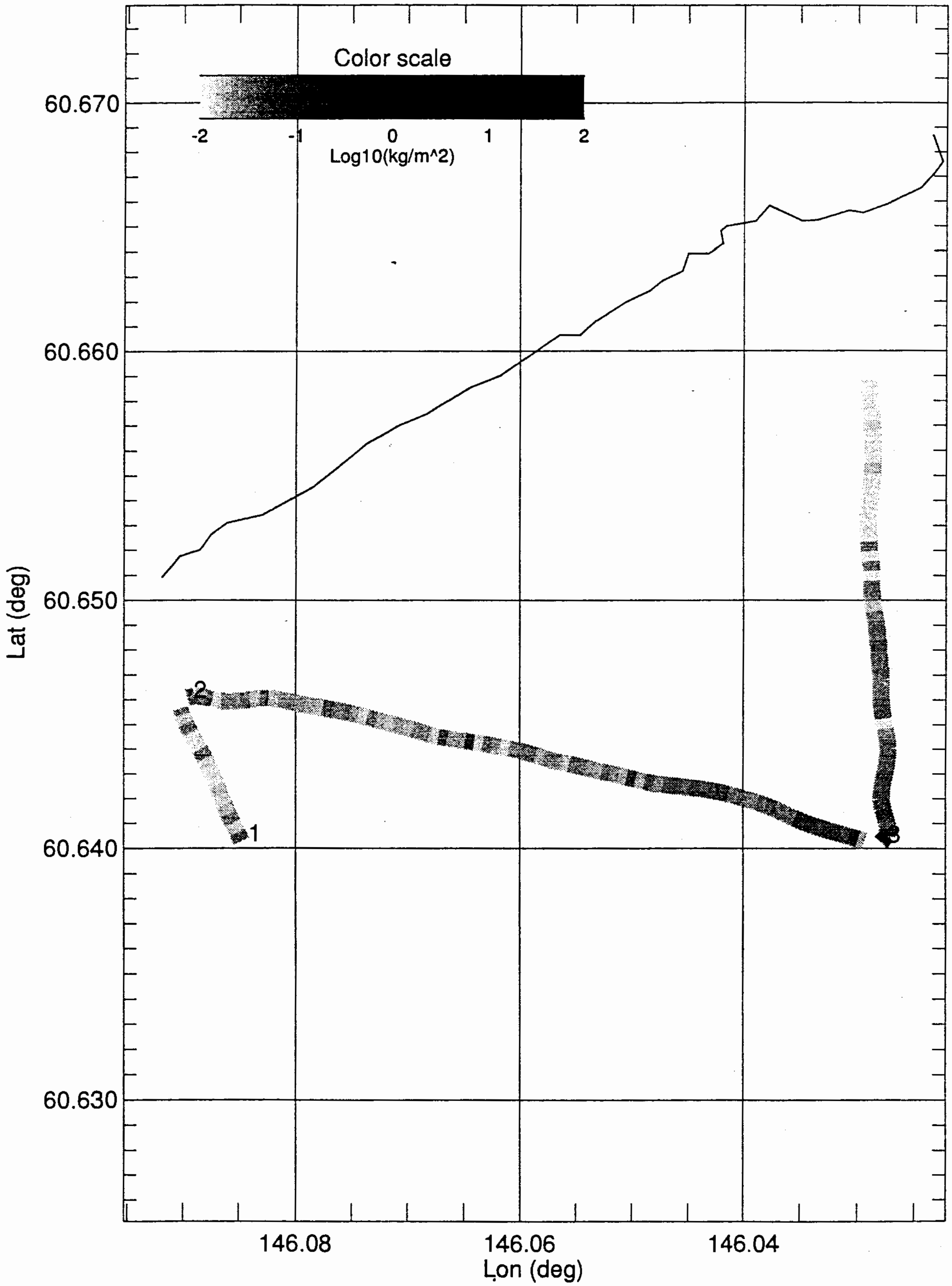

Figure 11. Sheep Bay (h9809) herring distribution

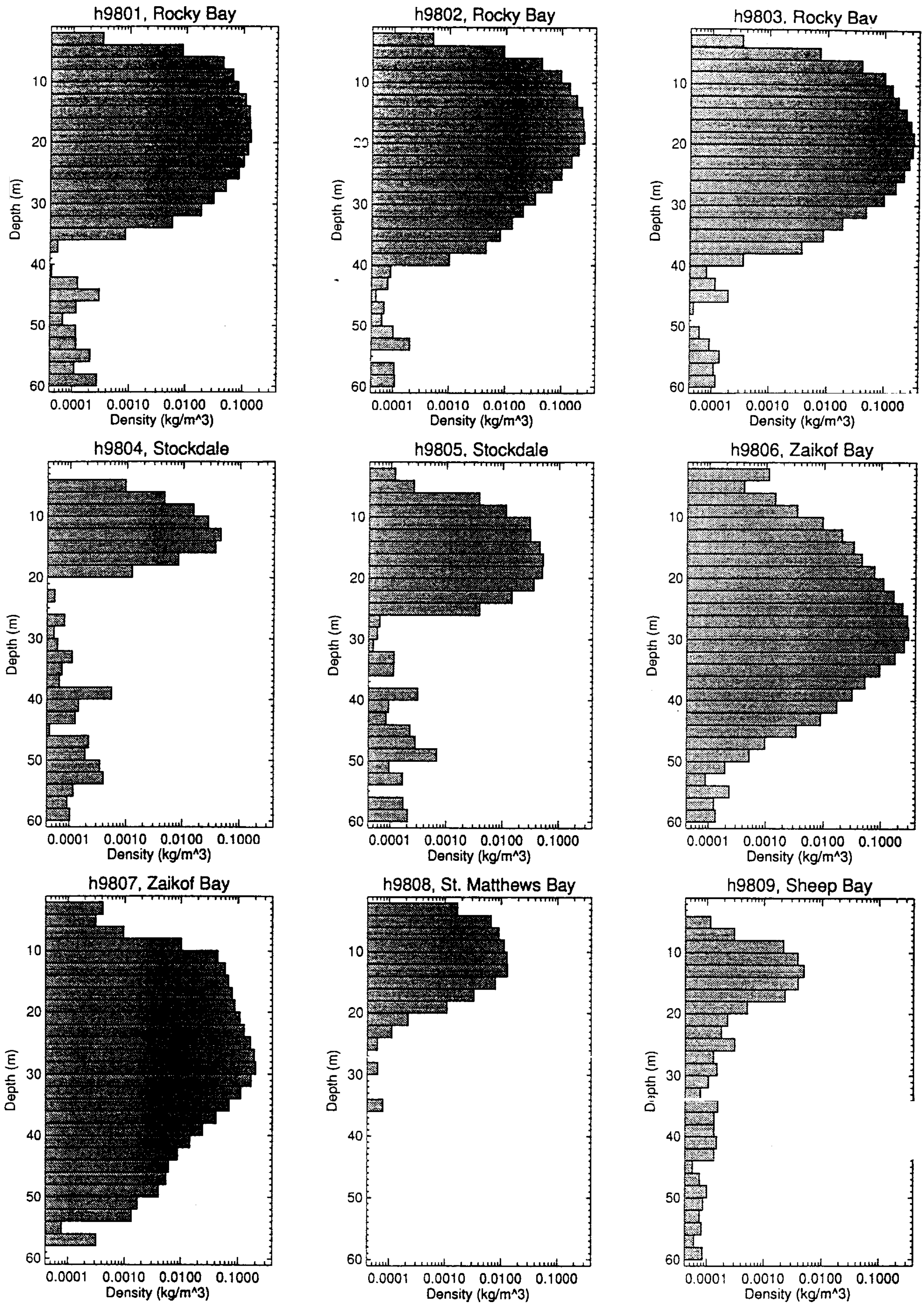

Figure 12. 1998 Herring depth distributions, F/V Miss Kayley. X-axis is log-scaled

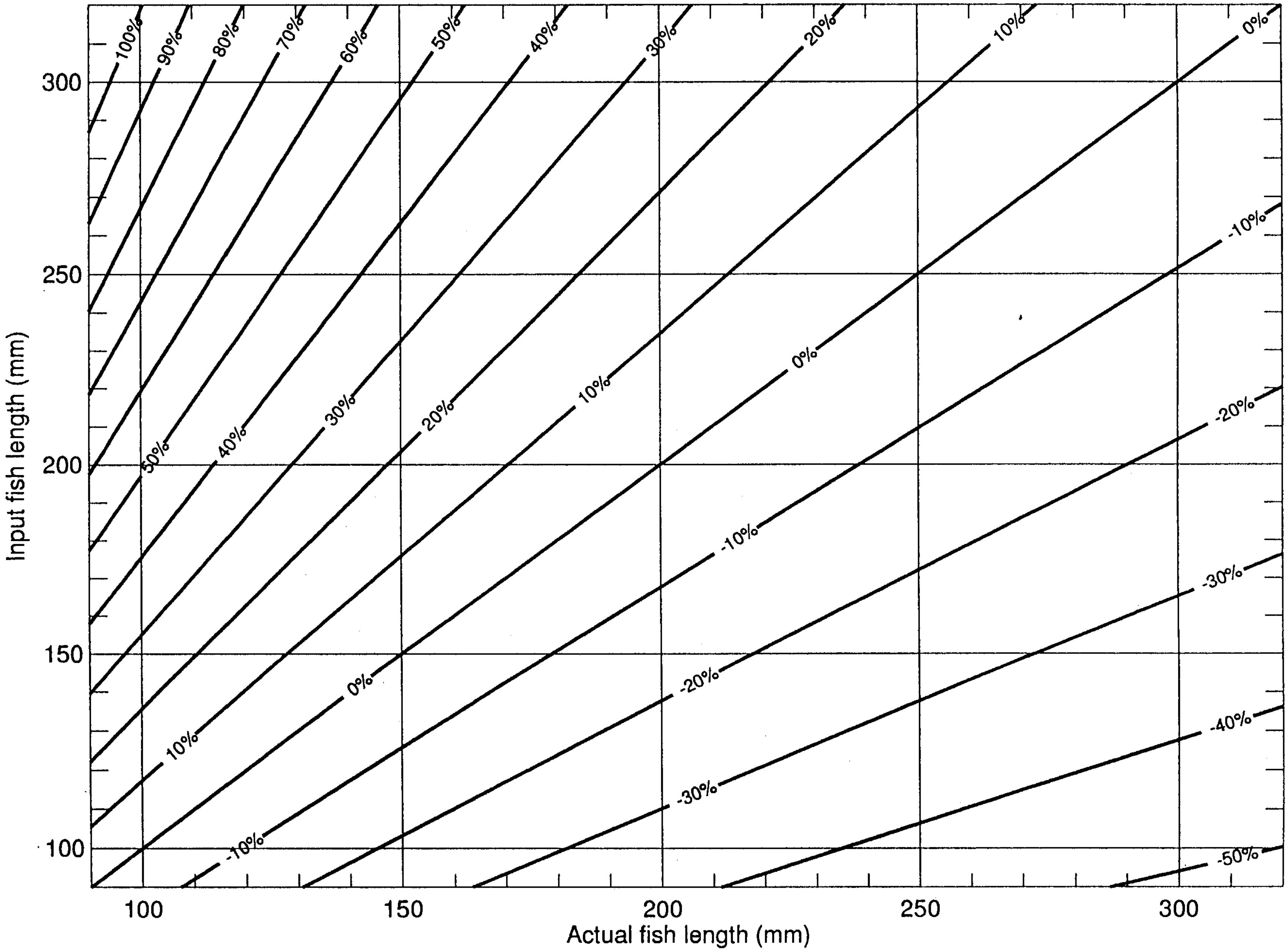

Figure 13. Percent error in biomass estimation due to incorrect length in Thorne model

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